REPORT OF THE 2009 INTER-SESSIONAL MEETING OF THE TROPICAL TUNAS SPECIES GROUP

(Madrid, Spain - April 20 to 25, 2009)

1. Opening, adoption of Agenda and meeting arrangements

The meeting was opened by Mr. Driss Meski, ICCAT Executive Secretary. Mr. Meski welcomed participants and highlighted the importance of the work conducted by scientists in ICCAT. Dr. Joao G. Pereira, General Rapporteur of the Tropical Tunas Species Group, chaired the meeting.

The Agenda (**Appendix 1**) was adopted without change. The List of Participants is included in **Appendix 2**. The List of Documents presented at the meeting is attached as **Appendix 3**. The following served as rapporteurs:

P. Pallarés	Items 1 and 9
N. Miyabe, C. Brown	Item 2
V. Restrepo	Items 3 and 7
D. Gaertner	Item 4
S. Cass-Calay, P. De Bruyn	Item 5
E. Chassot, A. Delgado de Molina, A. Fonteneau	Item 6
G. Scott	Item 8

2. Review of historical and new information on biology and fisheries

Since a large part of the discussions during this meeting focused on yellowfin tuna biology, in particular, issues related to growth, much of this section focuses on yellowfin in order to provide both a historical context as well as discussion details. Readers interested in similar information for skipjack and bigeye tuna are directed to the executive summary reports and relevant detailed reports for each species.

2.1 Yellowfin

2.1.1 Stock Structure and behavioral implications for fishery interactions

Yellowfin tuna is a tropical and subtropical species distributed mainly in the epipelagic oceanic waters of the three oceans. The sizes exploited range from 30 cm to over 170 cm (fish over 200 cm are occasionally caught). Smaller fish (juveniles) form schools in close association with skipjack and juvenile bigeye tuna, and are mainly limited to surface waters. These schools are strongly associated with floating objects or Fish Aggregating Devices (FADs), beneath which fish tend to be somewhat segregated by size. This association with FADs increases their vulnerability to surface fishing gears and it has been postulated that productivity and/or survivorship could be adversely impacted (*i.e.* fish transported into less productive waters while remaining associated with the large numbers of artificial FADs). Larger yellowfin are also found around FADs, although to a lesser extent than at smaller sizes, and form schools in surface and sub-surface waters. These larger fish remain vulnerable to surface fisheries and are also caught by longline and rod and reel.

Catch data (**Figure 1)** indicate that yellowfin are distributed throughout the entire tropical Atlantic Ocean, as well as in warmer waters in the Gulf of Mexico and following the warm currents along the coast of Brazil and the United States (a typical range of about 45^{o}N-45^{o}S off the western Atlantic coasts). Young fish represent a much higher proportion of the catch in the eastern Atlantic, although to a large extent this is a result of gear selectivity and fishing methods (*i.e.* the use of FADs) applied in the eastern Atlantic surface fisheries. In the eastern Atlantic, particularly in the Gulf of Guinea, both the thermocline and the depth profile of reduced dissolved oxygen levels are much shallower, which likely vertically compresses the available habitat with the result of increasing the vulnerability of yellowfin tuna to surface gears (Prince and Goodyear 2006). This habitat compression could affect the interpretation of abundance indices and potentially have implications on our perception of other descriptors, such as population size frequencies (depending upon any relationship between size and temperature/hypoxia tolerance).

The working hypothesis with respect to migration patterns is that the most yellowfin are born in the Gulf of Guinea, move to the western Atlantic over the next 2-3 years, and return to spawn in the Gulf of Guinea. This hypothesis is somewhat supported by catch-at-size distributions by area and a substantial number (41) west to east trans-Atlantic tag recoveries (**Figure 11**), although there have been only four east to west trans-Atlantic recoveries despite large numbers of releases. The available tagging data and analyses are discussed in further detail in section 4. The working hypothesis of migration patterns is likely an over-simplification of the movement patterns and rates, and additional information is needed to better describe and quantify movement. The Group recommended that conventional tagging programs be maintained at least at the higher historical levels and encourages the use of satellite/archival tags (noting that such studies are very limited for Atlantic yellowfin tuna, in stark contrast to other oceans) to improve our understanding of movement patterns, residence times and preferred habitat.

Spawning is known to occur in the equatorial zone of the Gulf of Guinea (**Figures 2 and 3)** peaking January to March, in the Gulf of Mexico (peaking May-August), in the southeastern Caribbean (peaking July-September), and off Senegal (April-June), Cape Verde (August-September), and Angola (December) (Shuford *et al.*, 2007). Although the relative importance of these spawning grounds has not been quantified, the Gulf of Guinea is considered to be the main spawning area based primarily upon the large numbers of spawners and recruits in the catch. Estimation of the relative importance of the spawning areas from catches alone is difficult as a consequence of the varying vulnerabilities of the fish by size, geographic area and time. Therefore, the Group reiterated its recommendation from the 2007 Inter-Sessional Meeting of the Tropical Species Group that further research be conducted using direct ageing (or other appropriate methods) capable of estimating birth month (which can be correlated to the various spawning areas). Sampling should be designed to be representative of the catch and/or stock.

Although the existence of separate spawning areas might perhaps imply separate stocks or substantial heterogeneity in the distribution of yellowfin tuna, based upon current interpretations of catch and tagging data as well as data limitations with respect to evaluating mixing, a single stock for the entire Atlantic is assumed as a working hypothesis.

2.1.2 Natural mortality

Natural mortality is assumed to be higher for juveniles than for adults, as has been shown in tagging studies in other oceans. The natural mortality rates have been demonstrated to be size-dependant in bigeye, skipjack and yellowfin tuna in the western tropical Pacific Ocean using tagging data (Hampton, 2000). This study estimated that M was an order of magnitude higher in the smallest size-class in comparison to mid-sized fish, underlining the importance of accounting for size- or age-specific natural mortality rates. The Group has addressed this by defining the natural mortality vector at a level of 0.8 for ages 0 and 1, and 0.6 thereafter.

The Group recognized that many stock assessment results and projections are sensitive to assumptions about natural mortality and discussed options for considering alternative vectors in sensitivity analyses. Document SCRS/2009/038 examined the influence of some alternative assumptions regarding natural mortality on evaluations of the impact of time-area closures on the YPR and SPR of yellowfin tuna. The Group discussed these results, and requested that among the alternatives considered should be a natural mortality vector which shows a relatively high initial mortality, declining continuously with increasing age, such as a "Lorenzen M vector" (Lorenzen 1996).

In order to parameterize the Lorenzen M function, the Group needed to provide an estimate of a hypothetical constant M vector which would produce the same survivorship as the Lorenzen M vector. This estimate was obtained using the Hoenig (1983) method, assuming a maximum age in an unfished population of 10 years (consistent with the longest observed worldwide tag returns). The resulting Lorenzen M vector is compared to the current working hypothesis in **Figure 4**. The implications of the different assumptions of M on evaluation of time-area closures will be evaluated in Section 5.

2.1.3 Growth

Growth rates have been described as relatively slow initially, increasing at the time the fish leave the nursery grounds. The working hypothesis for Atlantic yellowfin tuna is based upon work by Gascuel *et al.* (1992), who examined size frequency modes and fit a two-stanza model. Nevertheless, questions remain concerning the most appropriate growth model for Atlantic yellowfin tuna. A recent study (Shuford *et al.*, 2007) developed a new growth curve using daily growth increment counts from otoliths. The results of this study, along with other recent hard part analyses, did not support the concept of the two-stanza growth model. New documents presented at this meeting, and subsequent extensive discussions by the Group, addressed the relative merits and potential drawbacks to each approach to modeling the growth.

Figure 5 compares the two growth curves to each other and to the overall catch-at-size (1970-2006) available for the last yellowfin assessment. The two-stanza model estimates that fish grow slowly during the first year or more of life; a more rapid growth from post-larval stages to the size of recruitment into the fishery is assumed (i.e. an unspecified third, early stanza), but not captured by the model. The estimated L_∞ is near the largest sizes occurring in the catch, but falls below the maximum sizes that are caught (albeit infrequently). The Shuford *et al.* growth curve was fit to the von Bertalanffy growth function and predicts an L_∞ that exceeds the largest sizes occurring in the catch (although this does not occur until ages well beyond those that have been sampled). The L_0 predicted by the Shuford *et al.* model is more realistic than that explicit from the Gascuel *et al.* two-stanza model, but it should be stressed that this is understood and, as the accurate depiction of growth prior to recruitment is not critical for most stock assessment applications, this should not be considered heavily in the evaluation of the suitability of the two-stanza model for describing growth in the fished population.

The two growth models exemplify an ongoing debate for tuna assessment biologists worldwide. It is common for models developed from length-frequency data to demonstrate a two-stanza pattern, and tagging data appears to fit a two-stanza pattern as well. Such results are consistently at odds with growth derived using ages obtained from hard-parts (otoliths, dorsal spines, etc.), which correspond well to the von Bertalanffy function. The Group discussed the vulnerability of each approach to inherent assumptions.

An analysis of length-frequency distributions potentially has the advantage of tracking changes in cohort size and growth rate over time, depending upon the ability to separate cohorts (made more difficult at older ages or if recruitment is protracted). However, fitting a growth model to the observed progression of length-frequency modes can underestimate the growth rate around the age of full recruitment due to the interaction of the selectivity of the gear(s) and the true size distribution of incoming cohorts. The ongoing incorporation of slower-growing fish sends to slow the increase in the modal size until all fish from a cohort is recruited; this phenomenon may be exacerbated if recruitment is protracted, which is likely for yellowfin tuna. It is difficult to evaluate the extent to which this may or may not have occurred with the data utilized in the Gascuel *et al.* study without independent (and accepted) size-at-age observations for estimates of the selectivity.

Using tag-recovery data to fit a growth model is also widely applied and potentially offers the best method to observe growth rates directly. The Group also considered that tagging data from short-term releases may be particularly useful for tracking growth patterns at different life stages. Unfortunately, there are few fish that are measured at both release and recapture (most recapture lengths are estimated), and there is concern about measurement error. Very slow or negative growth, as well as extremely high growth rates, are frequently observed. Objective criteria for the elimination of outliers are difficult to define, as the expected range of growth rates are dependent on age/length and the underlying growth model. Estimation of t_0 is not possible through tagging data alone, and assumptions about birth date can shift the perceived ages. The Group discussed the possibility that the tagging process could adversely impact growth, but noted that tagging experts generally regard such impacts as negligible.

The use hard parts for ageing could offer several advantages, including obtaining observations for fish prior to recruitment to the fishery, and avoiding many of the limiting assumptions above. However, such samples may also be subject to selectivity, and the accuracy of the ages is dependent upon the ability to read growth increments and the degree to which they correspond to true age.

Several analyses were conducted during the meeting to examine the differences between the two models. A simple visual comparison of the growth curves estimated by Gascuel *et al.* and by Shufford *et al.* suggests that the basic underlying data used for fitting differed substantially. For this reason, a visual comparison of the 2 datasets was made (**Figure 6**). The data used were the lengths and corresponding otolith age readings by Shufford *et al.*, and the modal lengths at age from Gascuel *et al.* (Table 2 in their paper). The comparison shows that the two datasets are rather different in several aspects, as follows:

1) With the exception of fish around 40-50 cm, there is little overlap in the data (**Figure 2.1.6**, top left). Note that the age estimates from both studies are intrinsically different in nature: those from Shufford *et al.* are direct age readings from otoliths, while those from Gascuel *et al.* are modal lengths for the size frequencies of EU-PS fisheries in a given time period. Note that the Gascuel *et al.* data assume that all fish are born in January 15th; in contrast, the Shufford et al. data make no explicit assumption of birth

date, although direct age estimates also make some assumptions that affect the readings of absolute age. If the Gascuel *et al.* data are arbitrarily shifted to younger ages by about 0.5 years, the two datasets coincide much better (**Figure 6**, top right; similarly, the Shufford et al. data could be shifted in the other direction, to get the same effect). This suggests that the otolith age readings and the assumed birth dates for the modal lengths are inconsistent with each other.

2) The Shufford *et al.* dataset shows considerably more variability than the Gascuel *et al.* modal lengths. This could partly be explained by the fact that the Gascuel *et al.* observations are modes rather than size frequency distributions. But it can also partly be explained by the explicitly assumed birth date in this data set. If the Gascuel *et al.* dataset is not only shifted, but also a normally distributed error term is added (mean=0, s.d.=0.2), the overall variability in the two data sets is more similar (**Figure 6**, bottom left). The Gascuel *et al.* dataset would of course become even more variable with higher variability in assumed birth date (**Figure 6**, bottom right; mean=0, s.d.=0.4).

3) The two-stanza shape of the Gascuel *et al.* dataset is not apparent in the Shufford *et al.* data. Several factors such as size-selective sampling could cause this difference.

In conclusion, the two datasets seem to be different in several aspects, suggesting that combining the two datasets in order to estimate a combined growth curve would not be very helpful at this stage. These comparisons do not imply in any way that one data set is superior to the other.

It was noted that the sex-ratio of yellowfin tuna in the catch varies by size, with males becoming increasingly predominant above 140 cm. Similar trends are found in both the EU purse seine data from the eastern Atlantic (**Figure 7**, obtained from Abidjan landings) and the US pelagic longline data from the western Atlantic/Gulf of Mexico (**Figure 8**). There are a number of potential explanations for this phenomenon, including sex-specific differences in natural mortality rate, and availability/vulnerability to the gears. One explanation is that there is sexually dimorphic growth. The scarcity of very large females in the catch could occur if they follow a growth curve with a lower L_∞. Many of the difficulties encountered in fitting a growth model for yellowfin tuna could be explained if there are, in fact, two separate underlying distributions.

Document SCRS/2009/040 evaluated the potential impact on stock assessment results if the alternative (Shufford *et al.*) growth model were assumed. Based upon the VPA model only, the results suggest that there is a minimal impact on estimates of current status, predicting a slightly more optimistic status with a 1% reduction in the estimate of $F_{current}/F_{MSY}$ and a 6% increase in the estimate of $SSB_{current}/SSB_{MSY}$ (**Figure 9**). However, examination of the estimated benchmarks and the stock status trend (**Figure 10**) would suggest that MSY would be achieved at very low spawning stock biomass levels relative to the virgin levels. This may imply that a stock following the Shufford *et al.* growth model may be more vulnerable to recruitment overfishing if MSY is a management target.

Document SCRS/2009/037 presented a proposal to use a model to evaluate various yellowfin tuna growth hypotheses in terms of their ability to explain existing assessment data. This study seeks to use total and partial negative log-likelihood values in conjunction with fits to the existing length compositional data to evaluate the tested hypotheses. Specifically, this study proposes to use the statistical catch-at-age model stock synthesis to evaluate existing yellowfin tuna growth hypotheses to increase understanding of the various hypotheses and how they result in different model fitting tradeoffs. Model outcomes will be evaluated in terms of the total as well as the partial likelihoods. An AIC-like criterion will be utilized to compare the likelihood values between model configurations with regard to the number of estimated parameters. Visual fits to the observed length compositional data as well as the hypothesized growth model will be examined for residual patterns and evidence of biases possibly introduced from the size-at-age data. Size-at-age observations from the various studies will be compared to the various growth models, both fixed and estimated, and residuals examined for evidence of fit and lack thereof. The Group discussed this proposal and agreed that it was a reasonable approach that should be undertaken, but cautioned that care should be taken, for model configurations where size-at-age observations are utilized, to avoid biasing results in favor of hard part analyses.

The Group acknowledged that questions remain regarding the growth of yellowfin tuna and agreed that it would be useful to determine which growth model would be the most appropriate to apply for stock assessments. The Group recommended that various models be applied to the available length-frequency, tagging and direct ageing data to evaluate their relative goodness-of-fits. The Group also recommended that efforts to derive age estimates from otoliths be continued and expanded to include more large fish to improve estimates of L_∞ and more small fish (particularly between 0 and 40 cm) to provide greater resolution to the growth of young fish, where the differences in trends between the two models are greatest. It was suggested that samples could be collected from among the *faux poisson* landed in Abidjan. Considering the possibility that there may be sexually dimorphic growth, sex id should be collected whenever possible for specimens used in growth studies.

2.2 Bigeye

With regards to bigeye tuna, document SCRS/2009/035 provided new information on the Moroccan longline fishery. During the last decade, a new Moroccan longline fishery targeting swordfish has been developed in Atlantic waters. This fleet catches several by-catch species. Among them, about 800 tons of bigeye tuna were landed annually on average. Bigeye tuna are caught all year round, with higher catches from September to February. The size of fish ranges from 60 to 204 cm in fork length, with a mean length of about 104 cm, which corresponds to a round weight of about 28 kg. The average size of fish caught from August to December is smaller than that of fish caught during the rest of the year.

Since the area of operation is close to the Canary Island waters, similar fish sizes to those fish caught in Canary Island fishery are observed. Revised weight frequency data were provided to the Secretariat during the meeting. There were several questions on the geographical extent of fishing grounds and how the fishery operates. The standardized CPUE in weight of bigeye tuna shows a decreasing trend during the period 2004-2007. However, this trend should be interpreted with caution as this fishery is not targeted on bigeye tuna.

2.3 Skipjack

No new information on biology or fisheries was presented for skipjack.

3. Review of progress on data-mining efforts to recover historical tagging data and other information

3.1 Tagging data

No recent efforts have been made to recover historical tagging data for tropical tunas. Participants noted the possibility that some of the tag records from the special research programs were not in the ICCAT database. To illustrate this, a comparison was made between the database information for 1980-1982 and the number of tag release/recapture data for the skipjack year program (SKJ, as reported by Bard, 1986, Proc. ICCAT SKJ 1: 348-362). **Table 1** shows the comparison, indicating that a substantial number of records, primarily releases, are missing from the ICCAT database. The Group recommended that national Scientists and the Secretariat work diligently to recover these historical tagging data. In this respect, progress was made towards the end of the meeting when French national scientists provided to the Secretariat a data file that contains recoveries for the period 1965-1980 (although of yet unavailable format, which will be sent later on to ICCAT).

3.2 Information loss from the Data Record

For many years, several national scientists have suspected that a substantial part of the data available in the early years has been lost. In particular, it has been stressed that much of the Task II information published in the Data Record failed to be assimilated into today's ICCAT databases, especially for yellowfin size frequency data. A comparison was made between the number of Task II records contained in the database and in the published Data Records for tropical species (**Table 2**). This comparison shows little evidence to substantiate the claim of substantial data losses, at least for tropical tunas. Nevertheless, some data gaps were found in catch-effort data, such as for U.S. Sport fisheries (**Table 2**). The Group recommended that the Secretariat try to incorporate these historical catch-effort data in the database.

3.3 Information recovery from data elements not contained in the Data Record

Two national scientists present at the meeting made available a set of historical size data for yellowfin that they had available with them. After comparing against the Task II database, the following elements were found to be new:

Japan LL: 1956 to 1962
France BBI: 1965 to 1968
France PSLB: 1968
Spain BB: 1973

The Secretariat will incorporate these data into the database.

3.4 Other progress

Document SCRS/2009/045 presents historical information on the tuna landed by the Azores baitboats, recovered from tuna canneries that recorded for each landing, the weight and the number of the tuna purchased. Detailed records are available from 1963 to 1985, mostly for bigeye and skipjack, but also for albacore and bluefin tunas. Size frequency distributions were produced for those species, assuming that the mean round weight of each trip (actual observations) represents an average of the mean size of the tuna species caught available to the fishery. The Group was encouraged by this data mining as it could be particularly useful to estimate the size structure of the catches for a historical time period. During the meeting, the authors provided the information to the Secretariat to be included in the Task II database.

Document SCRS/2009/036 reported about an ongoing effort to recover historical logbook data from the Ghanaian fisheries. To date, logbook information from 1992-2007 has been recovered and transmitted to the Secretariat. These data could help improve the Task II database, particularly in terms of spatio-temporal distribution of the fleet over time. The Group was encouraged by this effort and expressed its hope that the logbook recovery will be completed soon. In addition, the Group suggested that it would be useful for Ghanaian National Scientists to think of ways in which more logbooks could be obtained from the fishing vessels in the future, so as to improve coverage. It was noted that canneries could perhaps assist in this task.

SCRS/2009/035 also presented information on individual weights (RW) of Bigeye tuna recovered for the period 2003-2007, collected from the fish market at the port of Dakhla in the southern of Morocco. The Group noted that these data, representing close to 8000 fish, will make a useful addition to the Task II size database.

4. Analyses of tagging data

4.1 Improvement of the tagging data base

Document SCRS/2009/034 presents the methodology and the 14 variables (e.g., species, date, fleet, gear, etc) used for correcting the current tagging database conducted by the secretariat in 2009. Furthermore the paper describes the comparison algorithm which numerates each possible comparison of similar tag numbers existent in the current data. One of the objectives was to identify whether the same tag number is in fact duplication, or, if it represents two or more independent tag events. The integral revision cross-checks all the information received during 2008 (including the entire US CTS conventional tagging database from NMFS in Miami) by the Secretariat in addition to the revision made in document (SCRS/2006/048) in relation to tropical tuna species, against the entire ICCAT database (440000 records). The revised tagging datasets now contains: 11085 releases (of which 2882 have recoveries) for yellowfin, 18216 releases (of which 1578 have recoveries) for bigeye, and 36206 releases (of which 6720 have recoveries) for skipjack. Left apart is a dataset with around 400 recoveries, where inconsistencies on the species (species released is different than species recovered) exists. This sub-set requires further analysis and possibly scientific contribution to be included in the ICCAT database.

4.2 Stock structure

No document or analyses on stock structure was presented during this session. Nevertheless, during the Working Group, the ICCAT secretariat prepared different maps of apparent trajectories by group size: juveniles (FL <70 cm), pre-adults (70 <= FL < 100 cm) and adults (LF>100 cm) and by quarters of the year (70 cm and 100 cm represent the approximate inflexion size in growth rate and the 50% size at first maturity, respectively). After screening the figures, due to the low number of tags released and recovered by quarter, pre-adults and adults of bigeye and yellowfin were represented on the same maps (**Figure 11**). Even, these maps are only qualitative (i.e., recoveries were not adjusted by the fishing effort exerted within each strata) it can be seen that the apparent displacement of tunas is relatively low compared to which it is observed in other oceans (specifically for skipjack). This pattern has some management implications since the mixing of the fish appears to be low ("viscosity" concept). In the case of yellowfin several West-East trans-Atlantic migrations have been reported over the years (from the eastern coast of USA to the Gulf of Guinea). The recent decrease in recoveries in the Gulf of Guinea for the yellowfin tagged in the West was likely caused by a decrease in the total number of releases in the West (**Figure 12**). It must be noted that except for one tag, no evidence of relationship was observed between the U.S. coasts and Venezuela or North Brazil areas yet (in contrast to the situation found for billfishes). With respect to bigeye, a few equatorial trans-Atlantic movements have been observed from the East to the West.

4.3 Growth

Due to the recent improvement on growth studies conducted on bigeye and skipjack, the Working Group focused only on growth studies based on tagging data for yellowfin. If there is a lack of agreement on a satisfactory growth model for this species, direct estimation of growth rate by size class with an integrated model such as Multifan-CL should be an alternative. Document SCRS/2009/042 showed, however, that apparent growth rates directly obtained from a combined set of tagging data from the Atlantic and from the Indian Oceans are biased due to the smoothing effect of time-at-sea. In both oceans, a non-linear relationship between growth rate and length at release was shown. The effect of time at liberty on the magnitude of the growth rate and on the shape of the relationship with length at release was explored by simulation. Because there are few observations by size class to accurately estimate growth rate for short times at liberty, a simple standardization procedure based on a GAM model was proposed. The corrected growth rate was estimated by fixing time at liberty at one day with the aim of reflecting an instantaneous growth rate (**Figure 13**). Since corrected values are sensibly lower than apparent growth rates, a second simulation combining estimated growth rates and median times at liberty by size class was performed, to validate this approach. The Group noted the large variability in growth rate by size at release for the Atlantic data, compared to the Indian Ocean data. It was clearly shown that the median growth rate by size class was a more robust estimator than the simple mean. A plot of the observed growth rate by length for times at liberty shorter than 90 days confirms the pattern previously described and the range of values adjusted from the GAM (**Figure 13**). However, further studies are required to explore why the corrected values are low compared to the apparent growth rate and compared to values calculated from the two-stanza model (from length frequency) and from the von Bertalanffy model (from hard part reading) (**Figure 14**).

With regards to the growth curve to be used for yellowfin tuna stock assessments, the question concerning the most appropriate model was discussed, with the consensus of the Group being that this issue should be the subject of a later workshop. In contrast to tagging and length frequency analyses, studies conducted from hard part analyses do not support the concept of the two-stanza growth model. The conventional von Bertalanffy model and a 5-parameter model (depicting in part the two-stanza shape) were compared with the aid of tagging data, by projecting lengths at release on each growth curve and then by plotting lengths at recapture after the corresponding times at liberty. The dispersion of lengths at recapture around the fitted curve give a raw indication about the accuracy of each model, at least for short times at liberty (**Figure 15**). It was shown that, depending on the fishing gears at release and at recapture, the pattern of dispersion, and as a consequence the interpretation about the accuracy of the models, can be different. Even if the apparent slow growth rate for small size classes might be biased due to a selectivity effect, the non-linearity in growth rate is partially taken into account by the 5-parameters model. Besides, the fact that different studies conducted in different locations and with different fishing gears converge to the same finding (i.e., consequently assuming different recruitment and selectivity patterns) might give more support to the biological assumption than to a selectivity effect (without rejecting this later aspect).

During the Working Group an analysis of tagging length increment data assuming a model close to the conventional reformulation of the Von Bertalanffy's equation (Kirkwood 19xx) was done. The results (for fish with time at liberty larger than 30 days) are: L_{inf}=234.98 cm and K= 0.26, which are close to the estimates obtained by from the Shuford *et al.* analysis of otolith readings. Note that t_o cannot be estimated from the tagging size increment data. The fit of the growth models for large fish is problematic due to estimates of L_{inf} being greater than the observed maximum lengths, regardless of the model used, and this might be problematic for stock assessment.

The Working Group recognized that growth studies should be conducted with different and complementary information (e.g., combining hard part reading, tagging data and size frequencies). The relative merits of different sources of information used to obtain growth curves were discussed by the Working Group. Hard part age determination (specifically for large fish) might be biased, whereas tagging analyses suffer no aging bias but may have measurement or reporting date errors.

4.4 Natural mortality

A major problem was detected during the Working Group with respect of the amount of release data by experiments which apparently are not present in the ICCAT tagging data base. The total number of releases present in the ICCAT database was compared with the values by tagging experiments reported into the scientific reports describing the operations conducted during different ICCAT year programs, such as Skipjack year program, Yellowfin year program, etc (see Section 3). It was seen that for some tagging countries, release data have been reported to ICCAT only when recoveries occurred. This situation will be investigated by the secretariat and by national scientists. Consequently, the lack of crucial information required to estimate natural mortality prevented such analyses (tag-attrition models, etc) during the Working Group. The usefulness of observer data to estimate reporting rates was discussed by the Working Group. However, since the probability of detection of a tag by observers on board purse seiners (where tunas are not caught fish by fish) is very low in contrast to longline fisheries in which this method has been applied successfully, it appears more reasonable to conduct seeding experiments within the framework of intensive tagging programs to estimate this parameter.

5. Evaluation of alternative time/area closures for reducing juvenile catches

5.1 Past closure [Rec. 99-01] and current closure [Rec. 04-01]

An analysis of the EU purse seine catches during the FAD moratorium [Rec. 99-01] was described in SCRS/2009/041. This document presents a set of figures of tuna catches by species and by area taken by purse seiners in the Atlantic during recent years. The main goal of this document was to show the major changes in the purse seine fisheries during recent years, and especially in relation to the moratorium on FAD fishing implemented during the period November 1997-January 2005. The results of this analysis indicate that the FAD moratorium did reduce the average annual catches on FADs by EU purse seiners during the moratorium period as well as up to 2007. A more detailed examination of the monthly catches by the EU purse seiners during the moratorium period demonstrates that catches were substantially reduced during the moratorium period, although compliance was not complete. The document also addressed the importance of purse seine and bait boat catches by Ghana, and the need to include this information in order to produce accurate analyses of effects of time area closures.

Document SCRS/2009/044 described a potential framework for investigating the effects of time-area closures using standardized indices of abundance from the EU purse seine fisheries. For this analysis Task II catch and effort data were used to investigate the effectiveness of two fishing moratoria in the Gulf of Guinea region. The catch and effort data for yellowfin and bigeye tuna were standardized using generalized linear models. These standardized CPUE series were then assumed to represent relative abundance in the different moratorium areas for the two different species. The preliminary results indicated that the larger moratorium outlined in [Rec. 99-01] had a greater effect on the abundance of tuna within the moratorium areas than that outlined in [Rec. 04-01]. The Working Group discussed this result, and found it generally consistent with other analyses of the FAD moratorium.

5.2 Closure proposed in Annex 1 of [Rec. 08-01]

5.2.1 Graphical display of Task II data

To further explore the effect of the various FAD and surface fishery time-area closures, the Working Group proposed that maps of catches of tropical tunas be constructed, and that the estimated catches by Ghana be included. To accomplish this, a simple assumption was made, that the Ghanaian fleet during the 1991-2007 period had the same species and size composition as the EU PS fishery on FADs (EU PS being the Task II file including various other flags belonging to EU vessel owners).

The overall yearly catches of Ghana (BB+PS) was then raised to the EU PS FAD Task II by species and for all the time and area strata fished for FAD by the EU fleet. This hypothesis is neither fully realistic nor ideal, as there have been obvious historical differences in the geographical distribution and behavior of the two fleets, for instance:

- Ghana vessels fishing much more in Ghana EEZ and much less in the area north of 5°N,
- Ghana vessels being more active in the moratorium strata, especially during its first years of EU spontaneous closure
- The very small tuna sizes that may be discarded by EU PS may be kept and landed by the Ghana fleet.

But, this simple and provisional hypothesis did permit construction of an estimated virtual task2 of the Ghanaian fleet, and this estimated data set has been added to the EU Task II on FADs allowing construction of fishing maps of the total FAD catches. The maps of these FAD catches were made for the period 1991-2007, and split between 3 periods: before the moratorium, during it and after the moratorium (**Figure 16**). This assumption may not be consistent with the more detailed Task II data for the Ghana fleet which was recently provided to the

Secretariat, but which was not yet fully available for evaluation by the Group. Additional analysis in the future will be required to test this assumption.

Additional diagrams were also made to show the estimated monthly FAD catches by species in three selected areas (**Figure 17**). These are useful to illustrate the changes in the time and space of these catches. For instance, they show clearly that the major catches on FADs that were observed in the moratorium area before its implementation have not been observed during recent years. For the fishing pattern observed during recent years, there is no major fishing season observed for the FAD fishing or any major stable fishing zone where FADs catches show a pronounced importance (**Figure 18**).

Another figure based on the same virtual data base also illustrates the yearly catches of small yellowfin and small bigeye (less than 60 cm) observed by 5°x5° area during the 1991-2007 period (**Figure 19**). This figure clearly demonstrates the impact of the first moratorium to widely reduce the catches of small BET in the closed area, but also its indirect effect to increase catches of these small fish in other strata.

5.2.2 Per-recruit analyses

YPR/SPR analyses were also performed to address the potential effects of reinstating the FAD moratorium [Rec. 08-01]. Specifically, the Working Group proposed to analyze the potential benefit in YPR and SPR of yellowfin and bigeye tuna under various multipliers of the current level of fishing effort. The method applied is described in document SCRS/2008/170. This method can be used to estimate the effects of changes in fishing mortality (F) by age, fleet, gear and/or area on estimates of YPR and SPR. Two types of analyses were completed. The first examined changes in the relative effort of FAD fishing. For this analysis, the effective fishing mortality on FADs (Ghana PS+BB and European and associated fleet fishing on FADs) and an aggregated fleet (all others: longline, non equatorial BB, European and associated fleet fishing on free school and other fleets) was varied from 0% to 200% of current[1] values. The second analysis was examined changes in the relative effort of the surface fleets (Ghana PS+BB and European and associated fleet fishing on FAD + Free School) and other fleets (longline, non equatorial BB, and other fleets), but was otherwise identical. Age-specific biological inputs (weight of catch, weight of spawning stock, maturity and natural mortality at age) and the resulting fishing mortality at age from the most recent virtual population analysis models (YFT: 2008; BET:2007) were used to parameterize the models.

YPR/SPR results for yellowfin tuna

If the current natural mortality assumptions are applied, reductions in the fishing mortality due to FADs (relative to current levels) are expected to result in improvements in YPR even if the fishing mortality of the other fleets increases (**Table 3; Figure 20**). However, increases in the effort of the other fleets greater than 30% will result in SPR falling below current levels unless simultaneous reductions of FAD effort occur (**Table 4; Figure 20**). Increases in the FAD effort of 10-20% can result in modest increases in YPR, but at the cost of reducing SPR levels below current levels. The Group also analyzed the effects of effort modification on the aggregated surface fleet (FAD + free school) and other fleets. The results of this analysis (**Table 5 and 6; Figure 21**) are similar to those described above, except that improvements in YPR are not possible unless the other fleets increase their fishing effort. These results can be explained taking into account the impact of the purse seine catch of large yellowfin tuna.

YPR/SPR results for bigeye tuna

If the current natural mortality assumptions are applied, reductions in the fishing mortality due to FADs (relative to current levels) are not expected to result in significant improvements in YPR unless accompanied by substantial increases in the fishing effort of the other fleets. (**Table 7; Figure 22**). But it is important to note that large increases in the effort of the other fleets can result in SPR falling below current levels unless simultaneous reductions of FAD effort occur (**Table 8; Figure 22**). The results also suggest that some increase in total effort could result in enhanced YPR, but at the cost of reducing SPR, sometimes to levels below current levels. The Group also analyzed the effects of effort modification on the aggregated surface fleet (FAD + free school) and other fleets. The results of this analysis (**Tables 9 and 10; Figure 23**) are very similar to those described above. This result implies that reductions in FAD or total surface effort could be expected to yield similar results for BET.

[1] Current FAA was defined as the geometric mean of FAA for the most recent three years of the assessment, excluding the terminal year.

YPR/SPR results for skipjack tuna

The Group did not conduct similar analyses for skipjack. However, taking into account the biological characteristics of this species, it was considered that the application of measures such as time-area closure should not produce gains in YPR but should result in lost in skipjack catches that would be proportional to the size of the area closed and the period of closure.

Effect of the assumed level of natural mortality

Document SCRS/2009/038 presented an evaluation of the effect of time-area closures on the YPR and SPR of Atlantic tropical tunas under various assumptions regarding natural mortality. It is evident that analyses of YPR and SPR are sensitive to the magnitude and shape of the assumed natural mortality function. The YPR and SPR results obtained by the Working Group using the current assumptions regarding M were compared to those obtained using a preliminary Lorenzen M vector constructed at the workshop. When the Lorenzen M vector was used, the results generally indicated that smaller reductions in FAD (or surface) effort could result in improvements to YPR, and that significant increases in the other fishing effort were more likely to result in SPR falling below current levels. However, because the true natural mortality vector is poorly known, and some other natural mortality functions are equally possible, the Group recommended that the current assumption regarding M be retained for the purposes of the present YPR/SPR analyses. Since the natural mortality vector will have important implications for the perception of stock condition, the Group recommended that additional research regarding natural mortality be completed before the next assessments of yellowfin and bigeye tunas.

Conclusion

The Working Group decided that the results of a YPR/SPR analysis be used in conjunction with the maps of catches in the moratorium area to inform the selection of appropriate time area closures. This discussion will take place in the future after the newly reported Ghanaian Task II data can be fully incorporated. In addition, the Working Group pointed out that in the near future there could be a return of part of the European and associated purse seine fleet from the Indian Ocean. Preliminary estimation of catches on FAD showed an increase of around 10-20% in 2008.

6. Evaluation of port sampling programs

6.1 Description of current programs, by fleet

6.1.1 European and associated flags fleet

The Spanish and French fleets represent the largest purse seine fleet in the Atlantic Ocean. Since the beginning of the fishery, catch and effort data have been collected. The sampling of the fish sizes landed has been conducted under the control of experts of the IEO and IRD (ex-ORSTOM) in close collaboration with the CRO and CRODT scientists in Côte d'Ivoire and Senegal.

Catch and effort

Catch and effort data have been collected through logbooks with a full collaboration of the French and Spanish purse seine (PS) fishing industries. This system was established in the Atlantic Ocean at the end of the 1960s and has been implemented regularly by most of the Spanish and French fleets, resulting in a very good, consistent, and detailed database obtained with nearly 100% of vessel coverage. This data base covers both the EU purse seiners and the vessels belonging to EU owners by fishing under third countries flags. The basic information of the logbooks is raised trip-by-trip to loading data. The total landings for the three major tuna species by the PS European fleet in the last years are given in **Table 11**.

Catch species composition and size-frequency

Multi-species sampling schemes have been permanently developed for the EU PS landings since 1980 to estimate the quantities of small YFT and small BET that are most often reported in the log books as SKJ. In 1984, the Working Group on Juvenile Tropical Tuna made a comprehensive analysis of this bias. To correct this bias, a procedure based on this multi-species sampling of catches has been put forward and routinely used by EU scientists to correct the Task I and Task II data that have been submitted to the ICCAT since 1980. In the 1990s, changes were introduced to the fishing strategy of purse-seiners, with the extensive use of floating objects such as FADs. The composition of species and size resulting from this type of fishing varies considerably in comparison to traditional fishing on free schools. This new stratification between the FAD and free schools fisheries has been introduced in the EU database and processing only since 1991 (when catches done on natural logs were already reported but not identified in the database). As a result of these changes, and after numerous studies, in 1997, an improved sampling system and a new data processing were put forward after a European Research Program. The current sampling system (multi-species size sampling, and two-stage simultaneous counting –with larger sizes of each sample–) has been defined and its objective is to improve statistics by bearing in mind the majority of factors that influence this fishery. The sampling design for purse-seiners has been defined using detailed analyses and is carried out according to a design based on three criteria: area, time and fishing mode.

Baitboats

For the EU bait boats (BB) unloading in Dakar, sampling is carried out following the same specifications as for purse-seiners, the only difference being that the sampling unit in this case is the entire boat instead of the well. However, the species composition given in the log books is considered to be unbiased (due to the quite large sizes of tuna caught) and it has been kept as the basis for the species composition of this fleet. The total landings for the 3 major tuna species by the BB European fleet in the last years are given in **Table 12**.

6.1.2 Ghanaian surface fleets

The tuna fishery in Ghana started in the early 1960s, targeting skipjack, with minor landings of juvenile yellowfin and bigeye. However in the past four decades, tuna fishing in Ghana have been characterized by three major changes: (1) a classical baitboat fishery catching few bigeye, (2) the introduction of FADs in the early 1990s which significantly increased the bigeye catches, and (3) the development of an association with purse-seiners and baitboats often sharing their catch at sea.

Sampling methodology

Initially, the sampling of tunas at port (quayside) is done following the ICCAT *Field Manual* (Miyake & Hayasi, 1972) and the *ICCAT Manual* (ICCAT, 2006-2009) where 100 individuals at random per vessel are measured and species are also identified. This sampling is conducted prior to the catch being sorted by the stevedores into individual bins (containers). It should be noted that there is no at-sea sampling by size or species. Since there is mixing of catches from different sets into the same well, it is generally not possible to associate samples in a well to a particular set (geographic position). The results of each sampling are then summarized by boat type and on a monthly basis and also presented to the ICCAT Secretariat (Task 1& II); logbook information is also partially submitted.

Since the reintroduction of purse seining, the practice of sharing of fish between purse seiners and baitboats at sea has become more prevalent. The apparent shifting and or 'mixing' of fish from different fish holds has made sorting and sampling at ports into species and size categories for the canneries more engaging. An ICCAT working group of Tema (Anon. 2004), after a careful analysis of the then-current sampling scheme, suggested that the standard procedure used was convenient, but necessitated a much larger sample size. At least 500 fish for species composition, based upon the sampling protocol /analysis made on European purse seiners, would be needed. Since 2005, as recommended in a project under assistance from JDIP, the sampling protocol AVDTH (Le Chauve, 2001) adopted by the French Purse seiners operating in the Atlantic Ocean has been used.

In conformity with the objectives of the Data Fund and JDIP dedicated at improving data collection and quality assurance [Res. 03-21], a lot of workshops and synthesis on the Ghanaian database has been carried prior to the adoption of the new software (SCRS 2003/010; SCRS2004/035; JDIP/SC3/06/05). Re-estimated Task 1 catches for the years 1997-2005 were computed for the Bigeye Stock assessment in 2007 using size composition ratio calculated from size sampling.

Recently, there has also been considerable recovery of logbook information from 1992-2007 from the tuna surface fleets which would add additional input to refining and improving the spatio-temporal distribution of fish caught by Ghanaian tuna vessels. With this new information, among others, consolidation of existing data to improve the nominal catch or otherwise determine the correlation between Task I and II would be enhanced.

Table 13 presents the Ghanaian catch by species for the period 1997-2007.

Observer program

Observer programs on board have also been initiated since 2006 under the JDIP and the Data Fund in Ghana to determine, among others, the degree of collaborative fishing strategies and also sample to determine catch and species composition, including estimates of by-catch and discards.

Recent results from the 2008 program (August-November 2008) indicate that over 80% of fishing was on FADs. Skipjack catches comprised over 60% of the total catch during the period. Size distribution of catches on FADs showed similar trends (30-90cm) with modes around 48 cm for Yellowfin and Bigeye. In comparison to the previous fishing positions of 2007, there has been slight shifts outwards off the normal narrow strip off Tema, with some vessels fishing now off Gabon-Congo and Liberia-Sierra-Leone. Some by-catch species recorded were from Purse seiners including the Sailors dolphin fish (*Coryphaena equiselis*). Two (2) humpback whales were observed on the September 29, 2008 (5 ^{o}42'N, 0^{o}51E) and some striped dolphins (5 ^{o} 18N 1 ^{o}05N).

Table 14 shows general catches (t) of the vessels in 2008.

6.1.3. Cape Verde´s statistical system on fisheries

The Statistical System on Fisheries in Cape Verde dates back to 1984, when a sampling scheme was proposed by Shimura within the framework of the Committee for the Central Eastern Atlantic Fisheries (CECAF). Since that time, the system has been maintain and considerably improved. The system includes two components: the artisanal fishery and the industrial fishery which are comprised of hand line, purse seiners and baitboats.

The Statistical System for the artisanal fishery is based on two fundamental aspects:

- A sampling plan to assess the catches and fishing effort; and
- An annual inventory of the fishing means in all the fishing communities to have an account of the number of boats, motors, nets and fishermen.

The sampling plan has area stratification by islands and time stratification by months of the year. The nine islands of the archipelago are considered nine strata, as are the 12 months of the year. The landing ports are the primary units selected within the strata. There is an 18% total coverage rate of the 97 landing ports in Cape Verde. In spite of the considerable heterogeneity among the islands, it can be verified that the coverage rate varies between 6% and 75%. The sampling ports are selected based on the number of boats, the fishing gears, as well as accessibility. Six random samples are taken each month to calculate catch and effort. The data collected serve as the base to calculate the monthly catches at each sampling port. Initially, five boats of each gear should be sampled during the sampling days, and information should be collected on the following parameters: catch by species, effort, date and time of departure, date and time of arrival, gear used, type of school, number of fishermen and the price of the fish.

With regard to the industrial fishery, an interviewer is present during the entire time at the industrial landing ports. Further, the same persons conduct a thorough collection of catch data and fishing effort every day and month of the year.

Data processing

For the artisanal fishery, at each landing port, from catch and effort data, and by gear and by species, monthly estimates by port are obtained using a factor to extrapolate the number of working days of the month and the number of sampling days. After obtaining the monthly estimates by gear and by species for the sampling ports of one island, monthly estimates for this island are calculated by a factor to extrapolate the number of boats of the island and the number of boats of the port(s) sampled. The number of boats (by fishing gear) for each island is obtained from a general census, which is taken annually at all the landing points of each island. For the industrial fishery, the data collected by the interviewers are not extrapolated. Instead, the sum of the data collected at the industrial ports is used.

The data are processed and published annually in the "Statistical Bulletin" in printed format. The catch data on tunas have increased from about 4,000 t in the early 2000s to about 15,000 t in the recent years **(Table 15)**.

6.1.4 Estimates of "faux poisson" catches

A sometimes significant part of the fish caught by the tuna fleet does not enter the official marketing circuit of the canning industry: very small, damaged, badly conserved tuna or non-commercial species such as the smaller tuna (frigate tuna or little tunny), marlins and other species of billfish, rainbow runners, etc. Depending on the case (landing port, vessel size), these fish can be discarded at sea, or kept on board and landed as there are important local markets in Dakar, Abidjan and Tema. Quantities of “faux poisson” landed in Abidjan have been tentatively estimated since the early 1980s based on surveys and counts of pickup cars and small trucks conveying fish from the fishing port. Estimates are currently made by two informers in the port, one working by day and the other at night. All these amounts are estimated visually, since there is no chance of direct weighting. Informers identify and count the number of units loaded each day. They also make a visual estimate of specific composition in percentages, noting them down on the market fish forms.

Skipjack was the major species landed as “faux poisson” with an annual estimated average of more than 9,500 kg landed by all fishing flags on the local market during 2004-2007. For yellowfin, the annual average weight of total “faux poisson” landed was about 1,900 t during 2004-2007.

6.1.5 Côte d’Ivoire artisanal fishery

The artisanal maritime fishery is mainly carried out by Ghanaian fishermen that fish with drift gillnet off Abidjan and San Pedro, two ports in Côte d’Ivoire. In the Abidjan area, the landings are carried out five days per week. These landings are monitored by interviewers whose tasks are to record the number of trips and to determine, for some landings, the species composition and the sizes of billfish, sharks, rays and small tunas. For the first three groups of fish, size sampling is extensive while for the group of small tunas, less sampling is carried out. The landings, in number, are mainly comprised of skipjack tuna (small tunas), which accounted for around 3 million fish, or about 8,000 t in 2008.

6.2 Strengths and weaknesses of current programs

6.2.1 Port sampling for European and associated flags fisheries

Multi-species port sampling has been routinely used by ICCAT since the early 1980s to estimate size distribution and species composition of major tuna catch for the purse seine and bait boat fisheries of the European Union and Ghana. There is therefore a strong experience in such port sampling that is also used within the Indian Ocean (IOTC) and eastern Pacific Tuna Commissions (IAATC) since the mid-1980s and early 2000s, respectively. Data collection and processing are based on well described protocols and rely on large fish samples and the sampling programs show a good homogeneity between fishing fleets (French, Spanish and associated flags) and consistency in time despite some temporal modifications used to improve data quality and to address major changes in the fisheries such as the development of FAD-fishing in the mid-1990s.

Port sampling relies on the quality of information provided by fishing masters, freeze engineer (logbooks and well maps), and fishing industries (landings). Inference from samples to total catch can therefore be affected by poor quality information (e.g. underestimation of large yellowfin in FAD-sets) or lack of compliance with scientists (e.g. Ghana).

However, Lawson (2008)[2] recently showed that there might be strong differences between catch composition derived from port sampler and observed data and that port sampling scheme results may be hampered by various types of sampling biases. In particular, there is currently no stratification based on the size/weight of the purse seine fishing sets whereas preliminary analyses seem to indicate consistent patterns in the changes in catch composition (percentage of yellowfin and skipjack) with set weight for FAD-fishing. Lawson (2008) also raised issues about sampling bias such as well mixing and grab sampling. Such biases could be low in the Atlantic Ocean compared to the western Pacific regarding the non-separation by weight categories aboard EU and Ghanaian vessels and the large number of samples collected, respectively. These potential biases as well as all potential problems related to the changes in the sampling and data processing schemes used in the Atlantic will

[2] Lawson T (2008) Factors affecting the use of species composition data collected by observers and port samplers from purse seiners in the western and central Pacific Ocean. Scientific Committee Fourth Regular Session. WCPFC-SC4-2008/ST-WP-3.

be analyzed and discussed during the international Working Group organized in Sète in June 2009 (section 6.3.1). It is expected that the comparison of the various sampling and data processing methods used in the various areas and RFOs may help to improve the Atlantic purse seine databases.

6.2.2 Discussion on Ghanaian statistics

Ghana has provided to ICCAT during the last 35 years a wide range of Task II data obtained from log books and from port sampling on Ghanaian and foreign tuna fleets. However, depending of the years, the coverage and quality of this data base are of variable coverage and quality. Significant sampling of the Ghanaian tuna fleet has also been done during some years by CRO in Côte d'Ivoire. As a consequence, most of the Ghanaian data, including task1 data, are somewhat questionable especially during certain years or periods. As a result, the current Ghanaian data may lead to inaccurate stock status evaluations and diminish the accuracy of advice the SCRS can offer the Commission on the effectiveness of time-area closures. It was recognized that a lot of efforts have been developed by Ghanaian scientists with the full support of the ICCAT secretariat during recent years, but unfortunately the present Ghanaian data bases used for stock assessment are still far from being consistent and reliable. Many of these problems were already discussed by the Ghanaian Data WG (ref: 2004?).

One of the pending question in the Ghanaian size distribution is the rarity of large yellowfin over 10 kg in the sampled catches: these large yellowfin are very rare in numbers and in weight (< 10%) since 1991 in the Ghana PS samples, when they are each year very significant in the samples taken on the FAD-associated schools caught and samples on EU PS in the same strata. The causes of this significant difference are not understood. This question is of major importance as yearly yellowfin catches by Ghana have been reaching a high level around 20,000 tons /year, more than 15% of the total catch during recent years (1999-2007).

This question of Ghanaian yearly catches and sizes is now of major importance for the SCRS tropical tunas stock assessments because the yearly catches by this fleet are now the most important ones in the Atlantic Ocean compared to catches by any other flag. Furthermore, these Ghanaian catches are taken on FAD, then with significant (but still poorly estimated) catches of small bigeye tuna.

Log book data recently submitted by Ghanaian scientists to the ICCAT Secretariat (**Figure 24**) have been confirming that Ghanaian fishing zones during recent years have been covering a quite wide fishing area between 5°N & 7°S and reaching 30°W. The very long trips of several Ghanaian purse seiners were noticed by Ghana scientists, showing 6-month trips at sea, and frequent at-sea transhipments on board freezer vessels landing in Abidjan (and rarely in Tema). These Abidjan landings tend to be more or less equally split between canneries (tunas over 1.5kg) and the local market of "faux poissons". It is assumed that these Abidjan landings are included in the Ghana Task I data submissions, but these catches in the local market may be underestimated and their species and size composition remain totally questionable. They probably contain a mix of major tunas, mainly of very small sizes (skipjack, bigeye, yellowfin) and of small tunas (*Sarda*, *Auxis*, *Euthynnus*) but in an unknown proportion.

The future routine sampling of these catches by CRO, on a regular basis, should be a priority and the scientific staff from CRO in Cote d'Ivoire could routinely sample, as currently is made with the European and associated fleets landings, the tuna landing of freezers that are carrying tunas caught by Ghanaian purse seiners (following the at-sea transhipment of these catches). Such sampling would require additional funding from ICCAT. CRO will soon evaluate this sampling program and its yearly cost and submit them for evaluation to ICCAT.

Ghana´s observer program on board some of its purse seiners has been presented, and such program is considered important and has added information to the ICCAT data base. The program allows validation of the species and size composition of catches as well as the proportion of FAD sets (that are assumed to be dominant). It has been noticed that some skippers did not cooperate with this observer program in the past, and the Group recommended that the observer program be reinforced.

In addition, there is some artisanal tuna catch taken as by-catch by the driftnet fishery targeting billfish in Ghana that are poorly characterized and not reported to ICCAT; this should not represent a large volume of tropical tunas.

6.3 Potential improvements

6.3.1 International working group on sampling

An international working group (WG) entitled "Tuna purse seine and baitboat catch species composition derived from observer and port sampled data" will be held from the June 15 to 19, 2009, at the Centre de Recherche Halieutique in Sète, France. Scientists from all tuna Regional Fisheries Organizations (RFOs), i.e. ICCAT, IOTC, IATTC, and WCPFC involved in sampling will assist the Working Group. The objectives are to compare and discuss the various methods used to estimate catch size and species composition derived from data sampling and processing, identify and estimate potential biases associated with each method, and propose new analyses and/or experiments to test the validity and improve sampling methods in current use within tuna RFOs worldwide.

6.3.2 Workplan to further improve catch and species composition of tuna species caught by Ghanaian surface fleets

The peculiar fishing strategies by Ghanaian surface fleets coupled with the intense use of FADs within narrow strips off the East Central Atlantic has often distorted the sampling schemes, and the estimates of species composition and catch of tuna species. Efforts at aimed at fully identifying juvenile tunas especially Yellowfin and Bigeye for improved statistics has been ongoing with vessel owners and stevedores operating from the Tema ports. This initiative has been rather thwarted by the apparent lack of interest from companies whose price differentials for the species are minimal.

In view of the sampling scheme described in Section 6.1.2, Ghanaian scientists should:

- revise the species composition of Task 1 and task 2 data for the period during 1989-2008 with the assistance of the ICCAT staff based on log-book data recently recovered,

- with the assistance of the ICCAT Secretariat and scientists from other institutes familiar with similar sampling programs; provide any other suitable information analyzed at the ICCAT Secretariat,

The Ghanaian observer program on board purse seiners was presented and it is satisfactory. However, the program should be encouraged and developed further to verify the species and the sizes caught by the fleet. It should be noted that some Korean vessel captains refused to embark the Ghanaian observers.

The program of Ghanaian observes onboard purse seiners was presented and was positive. Undoubtedly however, it should be promoted and developed verifying the species and the sizes of catches by the fleet. The refusal of some Korean captains to board Ghanaian observes, was noted.

In addition, it is important that scientists from Ghana meet EU scientists who are experienced in the AVDTH software as well as well versed in tropical tunas to scrutinize recent information observed, so as to improve and develop a robust system which could take into consideration any peculiarities emanating from the Ghanaian database. In the end of the scientific work proposed above (assistance of experts from the EU) progress work would be made to better understand the effects of the dynamics of the collaborative fishing strategies of the Ghanaian fleet on catch, catch-at-size and species composition among others. More effort would have to be made on the part of Ghanaian authorities (scientists, stevedores and fishing companies) to improve, distinguish between and record appropriately species composition, especially that of the bigeye.

7. Other matters

SCRS/2009/039 addressed, through simulation, issues related to assessing the appropriateness of relative abundance indices derived from nominal catch per unit of effort data. The paper examined in particular longline abundance indices for Atlantic yellowfin and bigeye tuna from fleets exhibiting range expansion. The spatial interaction between historical fleet dynamics and simulated population dynamics, including movement, was investigated through simulation. The paper suggested that the level of stock mixing is a less important contributor of bias than changes in the spatial distribution fishing relative to the population, at least for simple CPUE standardization models. Participants noted that the approach could be a very useful tool, similar to the LLSIM simulator that is being used by participants in the Working Group on Stock Assessment Methods. The

Group encouraged the authors to continue this valuable work, perhaps looking also at the issue of unbalanced data.

Concerning the statistics available from the ICCAT web page, previous versions of the Task II database arranged the data with catch in weight and catch in numbers in each row of the table. The “t2ce” table had many columns (weight and numbers for each species) but it was very easy to calculate average weights since they were contained in the same row. The latest February 2009 Task II database includes more species. In order to reduce the number of columns, a row of the original database is now split into two rows. There are two downsides to this new format. The first problems is that in order to pair a recorded catch weight to the numbers caught a matching algorithm must be run across all records that have paired catch data (approx 72,000 records). This entails many comparisons (approximately 72,000 factorial) which is computationally intensive. This is particularly the case, since there is no individual identification for a pair of catch datum. Matching a catch in weight with catch in numbers the matching algorithm must be run over other covariates such as Lat, Lon, Eff etc. A second problem is that there is not always a unique combination of these covariates with which to match data, meaning that some catch in weight and numbers that were recorded together can no longer be matched. The Group recommended that the full database be also made available on the web page as a text file so that expert users can download and import it into their own software.

8. Recommendations

8.1 Recommendations regarding tagging and growth

Growth

Approaches to estimate growth curves from multiple data sets (e.g. hard parts, tagging, length frequencies) have become common nowadays. However, there is no common view about the way in which different data types should be weighted. There are issues related to size selectivity, measured vs. estimated dimensions, loss of information from hard parts as fish grow larger, representativeness of samples, time-varying issues, etc. It was recommended that a methodological workshop on estimation of growth for tropical tunas, making use of information available, be held at a future date. Scientists from other tuna RFMOs should be encouraged to attend, as the same issues are important in all oceans.

For the Atlantic, there is a need to elevate the number of observations of size and sex at age for yellowfin (and bigeye) <40cm. Efforts should be made to obtain otolith ages from a representative sample of fish in this size range.

Tagging

Recent projects greatly expanded the available ICCAT tagging database for tropical tunas. The Working Group was able to jointly analyze these data during the workshop, which the Secretariat made available in advance of the meeting. Based on these analyses, it was found that there remains a considerable amount of information on the release of tagged fish, especially yellowfin, which are not available in the data set. This lack of information about total releases impedes use of the tagging data for estimating harvest rates. The Group recommended that National Scientists and the Secretariat work diligently and in concert to recover these historical tagging data.

The Group recommended that conventional tagging programs be maintained at least at the higher historical levels and encouraged the use of satellite/archival tags (noting that such studies are very limited for Atlantic yellowfin tuna, in stark contrast to other oceans) to improve our understanding of movement patterns, residence times and preferred habitat and life history characteristics including natural mortality. As measurements of size, location, and time of release, as well as upon recapture for all tagged fish provide critical information for advising on resource status, it is important that future tagging programs are conducted in a scientifically rigorous way and utilize an experimental design which can optimize their use for advising on stock status. Therefore, the Group reiterates that large-scale, coordinated and well designed tagging programs for tropical species stocks of high interest to the Commission, similar to those underway in other Tuna Commission Convention areas (e.g. IOTC, IATTC, WCPFC), should be initiated to provide data which will enable the SCRS to improve assessment advice. These large scale tagging are essential to provide basic information on stocks and fishery status independently of fishery bias.

8.2 Recommendations regarding data

Historical size samples

The Group recommended that the Secretariat try to recover the few elements of historical catch-effort data that are missing from the Task 2 database, but available from the *Data Record* or other sources.

The Group recommended that historical and present samples of size frequency (in contrast to raised and substituted size-frequency) be recovered and provided to the Secretariat in support of conducting stock evaluations that make use of the sampling fraction in calculations. Samples in 1cm, 1x1, monthly resolution are requested, whenever possible.

Ghana

The Group considers it critical to continue to improve the data used to characterize the species composition, distribution, and total catch of tropical tunas and especially those of Ghanaian flagged vessels. The Ghanaian production of major tuna species represents about 63,000 t per year, from an industrial surface fleet in excess of 35 vessels which landed in several countries. Sampling has improved recently due to investments through the various ICCAT capacity building efforts and cooperation between National Scientists. However, the level of sampling coverage for such a large amount of catches remains of concern. It is apparent that the Ghanaian infrastructure for collecting data, quality control, validation, and processing is far below that required to monitor catch and size composition with sufficient precision. The Group recommended that the Commission consider means to permanently increase the staffing and support level for these functions of monitoring and reporting on the catch level, species and size composition. It is noteworthy that much of the Ghanaian production supports highly profitable canneries which have the capability of assuring completeness, accuracy and reporting of catch data. In view of this, the Group recommends that the principals involved be consulted on the most appropriate means by which these infrastructure improvements could be instituted permanently. Collecting data directly from the canneries should be encouraged.

Resource	*Current*	*Required*
Head Scientist	1 temporary	1permanent
Sampling technicians	2 permanent, 2 temporary	6 permanent
Computer equipment	1 desktop computer	4 desktop computers, 2 laptops, internet connection, training
Software	AVDTH	AVDTH, statistical software, GIS
Sampling equipment	1 caliper temporary, 2 measuring boards	6 calipers, 8 measuring boards

In the near-term, some of the data collection shortfalls can be overcome by two additional actions recommended by the Group. First, two sampling technicians in Côte d'Ivoire should be funded to increase sampling the catch of Ghanaian flagged vessels landing in Abidjan. Second, observers need to be placed on the vessels landing in Abidjan in order to provide verification of logbooks and to sample catches at sea. This may require enhanced funding. The Group recommended that the Commission make use of capacity building funding mechanisms to fund the near-term needs.

Logbook information for a part of the Ghanaian fleet from 1992-2007 has been recovered and transmitted to the Secretariat. These data could help improve the Task II database, particularly in terms of spatio-temporal distribution of the fleet over time and will be critical to improving approaches to evaluate time-area closure effects. The Group was encouraged by this effort and expressed its hope that the logbook recovery will be completed soon. In addition, the Group suggested that it would be useful for Ghanaian national Scientists to think of ways in which more logbooks could be obtained from the fishing vessels in the future, so as to improve coverage. It was noted that canneries could perhaps assist in this task. In addition, efforts should be made to validate the logbook information, e.g. with observers and VMS. In the validation process Ghanaian scientists could be assisted by the Secretariat as well as by European scientists involved in tropical fisheries.

Other

The Group noted the publically available ICCAT data on the web, which enhances the transparency of the ICCAT scientific process. Recent evaluation of the Task II ACCESS data set from the web indicated a problem that there is not always a unique combination of covariates so that some catch in weight and numbers that were recorded together can no longer be matched. The Group recommended that the full database be also made available on the web page as a text file so that users can download and import it into their own software to avoid the problem now occurring in the ACCESS database.

9. Adoption of the report and closure

The Chairman again thanked the participants of the meeting for the hard work conducted and the Secretariat for the assistance provided. The report was adopted and the meeting adjourned.

References

ICCAT. 2006- 2009. ICCAT Manual. International Commission for the Conservation of Atlantic Tuna. In: ICCAT Publications [on-line]. Updated 2009. [Cited 01/27/]. http://www.iccat.int/en/ICCATManual.htm, ISBN (Electronic Edition): 978-92-990055-0-7.

Gascuel, D., A. Fonteneau, A. Capisano. 1992. A two-stanza growth model for the yellowfin tuna (*Thunnus albacares*) in the eastern Atlantic. Aquatic Living Resources, Vol. 5, No. 3, pp. 155-172.

Hampton. 2000. Natural mortality rates in tropical tunas: size really does matter. Canadian Journal of Fisheries and Aquatic Sciences [Can. J. Fish. Aquat. Sci./J. Can. Sci. Halieut. Aquat.]. Vol. 57, No. 5, pp. 1002-1010.

Kirkwood, G.P. 1983. Estimation of von Bertalanffy growth curve parameters using both length increment and age-length data. Can. J. Fish. Aquat. Sci. 40: 1405-1411.

Laslett G.M., Eveson, J.P., and Polacheck, T. 2002. A flexible maximum likelihood approach for fitting growth curves to tag-recapture data. Can. J. Fish. Aquat. Sci. 59: 976-986.

Laslett G.M., Eveson, J.P., and Polacheck, T. 2004. Estimating the age at capture in capture-recapture studies of fish growth. Aust. N.Z. J. Stat. 46: 59-66.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology, 49, 627–647.

Prince, E. D., and C. P. Goodyear. 2006. Hypoxia-based habitat compression of tropical pelagic fishes. Fisheries Oceanography 15(6): 451-464.

Restrepo, V. R, E. Rodríguez-Marín, J. L. Cort., C Rodríguez-Cabello 2007. Are the growth curves currently used for Atlantic bluefin tuna statistically different? Collect. Vol. Sci. Pap. ICCAT, 60(3): 1014-1026

Shuford, R.L., J.M. Dean, B. Stéquert, M. Morize. 2007. Age and growth of yellowfin tuna in the Atlantic Ocean, 2007. Collect. Vol. Sci. Pap. ICCAT, 60(1): 3330-341.

Table 1. Comparison of tagging information for tropical tunas held in the ICCAT database for 1980-1982 and the data reported during the Skipjack Year Program.

		ICCATdb						Bard(pag349)						diff (ICCAT-Bard)					
		Releases			**Recoveries**			**Releases**			**Recoveries**			**Releases**			**Recoveries**		
ReFleetCode	**ReYear**	**SKJ**	**YFT**	**BET**	**SKJ**	**YFT**	**BET**	**SKJ**	**YFT**	**BET**	**SKJ**	**YFT**	**BET**	**SKJ**	**YFT**	**BET**	**SKJ**	**YFT**	**BET**
BRA	1981	3			3			52	0	0				-49	0	0	3	0	0
CIV	1980	6	46	11	6	46	11	195	899		11	110		-189	-842		-5	-53	
	1981	48	275	138	48	275	138	909	3555		60	552		-861	-3142		-12	-277	
CPV	1980	5			5									5	0	0	5	0	0
	1981	56			56			2485	0		71		0	-2429	0	0	-15	0	0
	1982	744			744			4552	14	0	723	0	0	-3808	-14	0	21	0	0
CUB	1981	2			2			591	0	0	2	0	0	-589	0	0	0	0	0
	1982	1			1									1	0	0	1	0	0
EC.ESP	**1979**	6			6			74	1	0	7	0	0	-68	-1	0	-1	0	0
	1980	4		2	4			437	0	0	103	0	0	-433	0	2	-99	0	0
	1981	120			120			701	0	0	101	0	0	-581	0	0	19	0	0
	1982	310	1	4	310	1		1829	14	0	282	0	0	-1519	-13	4	28	1	0
EC.FRA	1980			2			2							0	0	2	0	0	2
EC.PRT	1981							11	0	0	3			-11	0	0	-3	0	0
	1982	3			3			92			4			-89	0	0	-1	0	0
JPN	1980	5962	1020	919	295	60	74	5976	1042	946	448	84	73	-14	-22	-27	-153	-24	1
	1981	6960		522	701		43	7000	0	519	747	0	37	-40	0	3	-46	0	6
KOR	1981	2	6	1	2	6	1	175	224	0	1	5	0	-173	-218	1	1	1	1
	1982	9	3		9	3		170	149	0	4	3	0	-161	-146	0	5	0	0
SEN	1980	6	2	7	6	2	7	119	98	240	8	7	5	-113	-96	-233	-2	-5	2
	1981	170	40	26	168	40	26	1391	699	432	160	29	21	-1221	-659	-406	8	11	5
	1982	877			877			2794	2	0	928	0	0	-1917	-2	0	-51	0	0
UNCL.FLEETS	1980			1										0	0	1	0	0	0
	1981	1			1									1	0	0	1	0	0
USA	1980	30	55		1			1412	166	0	6	3		-1382	-111	0	-5	-3	0
	1981	37	150	2										37	150	2	0	0	0
	1982	21	193	3		3								21	193	3	0	3	0
USR	1980	7			7			119			3			-112	0	0	4	0	0
	1981	5			5			874			3			-869	0	0	2	0	0
TOTAL		**15389**	**1791**	**1638**	**3374**	**436**	**302**	31958	9000		3675	929		-16569	-7209		-301	-493	

Table 2 Comparison between information held in ICCAT Task II database and the ICCAT *Data Record*.

	# of CEFF elements in			
Year	data Record	Data Base	% Completion	missing element
1950	2	1	50.0	USA/SPORT
1951	2	1	50.0	USA/SPORT
1952	3	2	66.7	USA/SPORT
1953	3	2	66.7	USA/SPORT
1954	4	3	75.0	USA/SPORT
1955	4	3	75.0	USA/SPORT
1956	4	3	75.0	USA/SPORT
1957	7	6	85.7	USA/SPORT
1958	6	5	83.3	USA/SPORT
1959	7	6	85.7	USA/SPORT
1960	8	7	87.5	USA/SPORT
1961	11	10	90.9	USA/SPORT
1962	11	10	90.9	USA/SPORT
1963	12	11	91.7	USA/SPORT
1964	13	12	92.3	USA/SPORT
1965	13	12	92.3	USA/SPORT
1966	13	12	92.3	USA/SPORT
1967	18	17	94.4	USA/SPORT
1968	18	17	94.4	USA/SPORT
1969	19	18	94.7	USA/SPORT
1970	19	18	94.7	USA/SPORT
1971	17	17	100.0	none
1972	21	21	100.0	none
1973	30	30	100.0	none
1974	33	33	100.0	none
1975	36	36	100.0	none
1976	42	42	100.0	none
1977	46	45	97.8	URSS/BB
1978	41	41	100.0	none
1979	47	46	97.9	Spain/PSG
1980	49	49	100.0	none
Total	**559**	**536**	**95.9**	

	# of YFT size element in			
Year	Data Record	ICCATdata base	% Completion	Missing element
1950	0	0	100	none
1951	0	0	100	none
1952	0	0	100	none
1953	0	0	100	none
1954	0	0	100	none
1955	0	0	100	none
1956	0	0	100	none
1957	0	0	100	none
1958	0	0	100	none
1959	0	0	100	none
1960	0	0	100	none
1961	0	0	100	none
1962	1	1	100	none
1963	1	1	100	none
1964	1	1	100	none
1965	3	3	100	none
1966	2	2	100	none
1967	5	5	100	none
1968	6	6	100	none
1969	9	9	100	none
1970	10	10	100	none
1971	9	9	100	none
1972	11	11	100	none
1973	16	16	100	none
1974	19	19	100	none
1975	27	27	100	none
1976	18	18	100	none
1977	16	16	100	none
1978	20	20	100	none
1979	22	22	100	none
1980	22	22	100	none
Total	**218**	**218**	**100**	

Table. 3 Percent change in YPR of yellowfin tuna with various modifiers on the fishing mortality of the FAD and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort on FADs	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	-100%	-75%	-54%	-37%	-23%	-11%	-1%	7%	14%	19%	24%	27%	30%	33%	35%	36%	37%	38%	38%	38%	38%
0.1	-96%	-72%	-53%	-37%	-23%	-12%	-3%	5%	11%	17%	21%	24%	27%	29%	31%	32%	33%	34%	34%	35%	35%
0.2	-92%	-70%	-51%	-36%	-23%	-13%	-4%	3%	9%	14%	18%	21%	24%	26%	28%	29%	30%	30%	31%	31%	31%
0.3	-88%	-67%	-50%	-36%	-24%	-14%	-6%	1%	7%	12%	15%	18%	21%	23%	24%	26%	26%	27%	27%	27%	27%
0.4	-85%	-65%	-49%	-35%	-24%	-15%	-7%	0%	5%	9%	13%	16%	18%	20%	21%	22%	23%	24%	24%	24%	24%
0.5	-82%	-63%	-48%	-35%	-24%	-15%	-8%	-2%	3%	7%	10%	13%	15%	17%	18%	19%	20%	21%	21%	21%	21%
0.6	-79%	-61%	-47%	-35%	-25%	-16%	-9%	-4%	1%	5%	8%	11%	13%	14%	16%	17%	17%	18%	18%	18%	18%
0.7	-76%	-59%	-46%	-34%	-25%	-17%	-11%	-5%	-1%	3%	6%	8%	10%	12%	13%	14%	15%	15%	15%	15%	15%
0.8	-73%	-58%	-45%	-34%	-25%	-18%	-12%	-7%	-2%	1%	4%	6%	8%	9%	11%	11%	12%	12%	13%	13%	13%
0.9	-71%	-56%	-44%	-34%	-26%	-19%	-13%	-8%	-4%	-1%	2%	4%	6%	7%	8%	9%	10%	10%	10%	10%	10%
1	-69%	-55%	-43%	-34%	-26%	-19%	-14%	-9%	-6%	-2%	0%	2%	4%	5%	6%	7%	7%	8%	8%	8%	8%
1.1	-67%	-53%	-43%	-34%	-26%	-20%	-15%	-11%	-7%	-4%	-2%	0%	2%	3%	4%	4%	5%	5%	5%	6%	6%
1.2	-65%	-52%	-42%	-33%	-26%	-21%	-16%	-12%	-8%	-6%	-3%	-2%	0%	1%	2%	2%	3%	3%	3%	3%	3%
1.3	-63%	-51%	-41%	-33%	-27%	-21%	-17%	-13%	-10%	-7%	-5%	-3%	-2%	-1%	0%	0%	1%	1%	1%	1%	1%
1.4	-61%	-50%	-41%	-33%	-27%	-22%	-18%	-14%	-11%	-9%	-7%	-5%	-4%	-3%	-2%	-1%	-1%	-1%	-1%	-1%	-1%
1.5	-59%	-49%	-40%	-33%	-27%	-22%	-18%	-15%	-12%	-10%	-8%	-7%	-5%	-4%	-4%	-3%	-3%	-3%	-2%	-2%	-2%
1.6	-58%	-48%	-40%	-33%	-28%	-23%	-19%	-16%	-13%	-11%	-9%	-8%	-7%	-6%	-5%	-5%	-5%	-4%	-4%	-4%	-4%
1.7	-56%	-47%	-39%	-33%	-28%	-24%	-20%	-17%	-14%	-12%	-11%	-9%	-8%	-8%	-7%	-6%	-6%	-6%	-6%	-6%	-6%
1.8	-55%	-46%	-39%	-33%	-28%	-24%	-21%	-18%	-15%	-14%	-12%	-11%	-10%	-9%	-8%	-8%	-8%	-7%	-7%	-7%	-7%
1.9	-54%	-46%	-39%	-33%	-28%	-25%	-21%	-19%	-16%	-15%	-13%	-12%	-11%	-10%	-10%	-9%	-9%	-9%	-9%	-9%	-9%
2	-53%	-45%	-38%	-33%	-29%	-25%	-22%	-19%	-17%	-16%	-14%	-13%	-12%	-12%	-11%	-11%	-10%	-10%	-10%	-10%	-10%

Table. 4 SPR (as % of maximum obtainable) of yellowfin tuna with various modifiers on the fishing mortality of the FAD and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort on FADs	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	100%	91%	82%	75%	69%	63%	58%	54%	50%	46%	43%	40%	38%	36%	33%	31%	30%	28%	27%	25%	24%
0.1	95%	86%	78%	71%	65%	60%	55%	51%	47%	44%	41%	38%	36%	34%	32%	30%	28%	27%	25%	24%	23%
0.2	89%	81%	74%	67%	62%	57%	52%	48%	45%	42%	39%	36%	34%	32%	30%	28%	27%	25%	24%	23%	21%
0.3	84%	77%	70%	64%	58%	54%	49%	46%	42%	39%	37%	34%	32%	30%	28%	27%	25%	24%	23%	21%	20%
0.4	80%	72%	66%	60%	55%	51%	47%	43%	40%	37%	35%	32%	30%	29%	27%	25%	24%	23%	21%	20%	19%
0.5	75%	68%	62%	57%	52%	48%	44%	41%	38%	35%	33%	31%	29%	27%	25%	24%	23%	21%	20%	19%	18%
0.6	71%	65%	59%	54%	49%	45%	42%	39%	36%	33%	31%	29%	27%	26%	24%	23%	21%	20%	19%	18%	17%
0.7	67%	61%	56%	51%	47%	43%	40%	37%	34%	32%	29%	28%	26%	24%	23%	21%	20%	19%	18%	17%	16%
0.8	64%	58%	53%	48%	44%	41%	37%	35%	32%	30%	28%	26%	24%	23%	22%	20%	19%	18%	17%	16%	15%
0.9	60%	55%	50%	45%	42%	38%	35%	33%	30%	28%	26%	25%	23%	22%	20%	19%	18%	17%	16%	15%	15%
1	57%	52%	47%	43%	39%	36%	33%	31%	29%	27%	25%	23%	22%	21%	19%	18%	17%	16%	15%	15%	14%
1.1	54%	49%	44%	41%	37%	34%	32%	29%	27%	25%	24%	22%	21%	19%	18%	17%	16%	15%	15%	14%	13%
1.2	51%	46%	42%	38%	35%	32%	30%	28%	26%	24%	22%	21%	20%	18%	17%	16%	15%	15%	14%	13%	12%
1.3	48%	44%	40%	36%	33%	31%	28%	26%	24%	23%	21%	20%	19%	17%	16%	15%	15%	14%	13%	12%	12%
1.4	46%	41%	38%	34%	32%	29%	27%	25%	23%	21%	20%	19%	18%	16%	15%	15%	14%	13%	12%	12%	11%
1.5	43%	39%	36%	33%	30%	27%	25%	23%	22%	20%	19%	18%	17%	16%	15%	14%	13%	12%	12%	11%	11%
1.6	41%	37%	34%	31%	28%	26%	24%	22%	21%	19%	18%	17%	16%	15%	14%	13%	12%	12%	11%	11%	10%
1.7	38%	35%	32%	29%	27%	25%	23%	21%	20%	18%	17%	16%	15%	14%	13%	12%	12%	11%	10%	10%	9%
1.8	36%	33%	30%	27%	25%	23%	21%	20%	18%	17%	16%	15%	14%	13%	12%	12%	11%	10%	10%	9%	9%
1.9	34%	31%	28%	26%	24%	22%	20%	19%	17%	16%	15%	14%	13%	13%	12%	11%	10%	10%	9%	9%	8%
2	32%	29%	27%	25%	23%	21%	19%	18%	17%	15%	14%	13%	13%	12%	11%	11%	10%	9%	9%	8%	8%

Table. 5 Percent change in YPR of yellowfin tuna with various modifiers on the fishing mortality of the "surface" and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort of the Surface Fleet	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	-100%	-88%	-77%	-68%	-59%	-50%	-43%	-36%	-29%	-24%	-18%	-14%	-9%	-5%	-2%	1%	4%	7%	9%	12%	14%
0.1	-82%	-72%	-63%	-55%	-47%	-40%	-34%	-28%	-22%	-18%	-13%	-9%	-5%	-2%	1%	4%	6%	8%	10%	12%	14%
0.2	-68%	-59%	-51%	-44%	-38%	-32%	-26%	-21%	-17%	-13%	-9%	-6%	-2%	0%	3%	5%	7%	9%	11%	12%	13%
0.3	-56%	-48%	-42%	-36%	-30%	-25%	-20%	-16%	-12%	-9%	-6%	-3%	0%	2%	4%	6%	8%	9%	11%	12%	13%
0.4	-46%	-40%	-34%	-29%	-24%	-20%	-16%	-12%	-9%	-6%	-3%	-1%	1%	3%	5%	6%	8%	9%	10%	11%	12%
0.5	-38%	-32%	-27%	-23%	-19%	-15%	-12%	-9%	-6%	-4%	-2%	0%	2%	4%	5%	6%	8%	9%	10%	10%	11%
0.6	-31%	-26%	-22%	-19%	-15%	-12%	-9%	-7%	-5%	-2%	-1%	1%	3%	4%	5%	6%	7%	8%	9%	9%	10%
0.7	-25%	-22%	-18%	-15%	-12%	-10%	-7%	-5%	-3%	-1%	0%	1%	3%	4%	5%	6%	6%	7%	8%	8%	9%
0.8	-21%	-18%	-15%	-12%	-10%	-8%	-6%	-4%	-2%	-1%	0%	1%	3%	3%	4%	5%	6%	6%	6%	7%	7%
0.9	-18%	-15%	-13%	-10%	-8%	-6%	-5%	-3%	-2%	-1%	0%	1%	2%	3%	3%	4%	4%	5%	5%	5%	6%
1	-15%	-13%	-11%	-9%	-7%	-6%	-4%	-3%	-2%	-1%	0%	1%	1%	2%	3%	3%	3%	4%	4%	4%	4%
1.1	-13%	-11%	-9%	-8%	-6%	-5%	-4%	-3%	-2%	-1%	-1%	0%	1%	1%	1%	2%	2%	2%	2%	3%	3%
1.2	-12%	-10%	-8%	-7%	-6%	-5%	-4%	-3%	-2%	-2%	-1%	-1%	0%	0%	0%	1%	1%	1%	1%	1%	1%
1.3	-11%	-9%	-8%	-7%	-6%	-5%	-4%	-4%	-3%	-2%	-2%	-2%	-1%	-1%	-1%	-1%	-1%	0%	0%	0%	0%
1.4	-10%	-9%	-8%	-7%	-6%	-5%	-5%	-4%	-4%	-3%	-3%	-3%	-2%	-2%	-2%	-2%	-2%	-2%	-2%	-2%	-2%
1.5	-9%	-9%	-8%	-7%	-6%	-6%	-5%	-5%	-4%	-4%	-4%	-4%	-3%	-3%	-3%	-3%	-3%	-3%	-3%	-3%	-3%
1.6	-9%	-9%	-8%	-7%	-7%	-6%	-6%	-6%	-5%	-5%	-5%	-5%	-5%	-5%	-4%	-4%	-5%	-5%	-5%	-5%	-5%
1.7	-9%	-9%	-8%	-8%	-7%	-7%	-7%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%	-6%
1.8	-10%	-9%	-9%	-8%	-8%	-8%	-8%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-7%	-8%
1.9	-10%	-10%	-9%	-9%	-9%	-9%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-8%	-9%	-9%	-9%
2	-11%	-10%	-10%	-10%	-10%	-10%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-10%	-10%	-10%	-10%	-10%	-10%

Table. 6 SPR (as % of maximum obtainable) of yellowfin tuna with various modifiers on the fishing mortality of the "surface" and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort of the Surface Fleet	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	100%	95%	90%	85%	81%	77%	73%	69%	66%	62%	59%	57%	54%	51%	49%	47%	45%	43%	41%	39%	37%
0.1	90%	86%	81%	77%	73%	69%	66%	63%	60%	57%	54%	52%	49%	47%	45%	43%	41%	39%	37%	36%	34%
0.2	82%	78%	74%	70%	66%	63%	60%	57%	54%	52%	49%	47%	45%	43%	41%	39%	37%	36%	34%	33%	31%
0.3	74%	70%	67%	64%	60%	58%	55%	52%	50%	47%	45%	43%	41%	39%	38%	36%	34%	33%	31%	30%	29%
0.4	67%	64%	61%	58%	55%	52%	50%	48%	45%	43%	41%	40%	38%	36%	35%	33%	32%	30%	29%	28%	27%
0.5	61%	58%	55%	53%	50%	48%	46%	44%	42%	40%	38%	36%	35%	33%	32%	30%	29%	28%	27%	26%	25%
0.6	56%	53%	51%	48%	46%	44%	42%	40%	38%	36%	35%	33%	32%	30%	29%	28%	27%	26%	25%	24%	23%
0.7	51%	48%	46%	44%	42%	40%	38%	37%	35%	33%	32%	31%	29%	28%	27%	26%	25%	24%	23%	22%	21%
0.8	46%	44%	42%	40%	38%	37%	35%	34%	32%	31%	29%	28%	27%	26%	25%	24%	23%	22%	21%	20%	19%
0.9	42%	41%	39%	37%	35%	34%	32%	31%	30%	28%	27%	26%	25%	24%	23%	22%	21%	20%	19%	19%	18%
1	39%	37%	35%	34%	32%	31%	30%	28%	27%	26%	25%	24%	23%	22%	21%	20%	19%	19%	18%	17%	17%
1.1	36%	34%	33%	31%	30%	28%	27%	26%	25%	24%	23%	22%	21%	20%	20%	19%	18%	17%	17%	16%	15%
1.2	33%	31%	30%	29%	27%	26%	25%	24%	23%	22%	21%	20%	20%	19%	18%	17%	17%	16%	15%	15%	14%
1.3	30%	29%	28%	26%	25%	24%	23%	22%	21%	20%	20%	19%	18%	17%	17%	16%	15%	15%	14%	14%	13%
1.4	28%	26%	25%	24%	23%	22%	21%	21%	20%	19%	18%	17%	17%	16%	15%	15%	14%	14%	13%	13%	12%
1.5	25%	24%	23%	22%	21%	21%	20%	19%	18%	17%	17%	16%	16%	15%	14%	14%	13%	13%	12%	12%	11%
1.6	23%	22%	22%	21%	20%	19%	18%	18%	17%	16%	16%	15%	14%	14%	13%	13%	12%	12%	11%	11%	11%
1.7	22%	21%	20%	19%	18%	18%	17%	16%	16%	15%	14%	14%	13%	13%	12%	12%	11%	11%	11%	10%	10%
1.8	20%	19%	18%	18%	17%	16%	16%	15%	14%	14%	13%	13%	12%	12%	11%	11%	11%	10%	10%	10%	9%
1.9	18%	18%	17%	16%	16%	15%	14%	14%	13%	13%	12%	12%	12%	11%	11%	10%	10%	10%	9%	9%	9%
2	17%	16%	16%	15%	15%	14%	13%	13%	12%	12%	12%	11%	11%	10%	10%	10%	9%	9%	9%	8%	8%

Table. 7 Percent change in YPR of bigeye tuna with various modifiers on the fishing mortality of the FAD and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort by FAD Fleets	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	-100%	-85%	-71%	-59%	-47%	-37%	-28%	-19%	-11%	-4%	2%	8%	13%	18%	22%	26%	29%	33%	35%	38%	40%
0.1	-96%	-82%	-68%	-56%	-46%	-36%	-27%	-18%	-11%	-4%	2%	7%	12%	17%	21%	25%	28%	31%	34%	36%	39%
0.2	-92%	-78%	-66%	-54%	-44%	-34%	-26%	-18%	-11%	-4%	2%	7%	12%	16%	20%	24%	27%	30%	33%	35%	37%
0.3	-89%	-75%	-63%	-52%	-42%	-33%	-25%	-17%	-10%	-4%	1%	7%	11%	15%	19%	23%	26%	29%	31%	33%	35%
0.4	-85%	-73%	-61%	-50%	-41%	-32%	-24%	-17%	-10%	-4%	1%	6%	11%	15%	18%	22%	25%	27%	30%	32%	34%
0.5	-82%	-70%	-59%	-48%	-39%	-31%	-23%	-16%	-10%	-4%	1%	6%	10%	14%	17%	21%	23%	26%	28%	30%	32%
0.6	-79%	-67%	-56%	-47%	-38%	-30%	-22%	-16%	-10%	-4%	1%	5%	10%	13%	17%	20%	22%	25%	27%	29%	31%
0.7	-76%	-65%	-54%	-45%	-36%	-29%	-22%	-15%	-9%	-4%	1%	5%	9%	13%	16%	19%	21%	24%	26%	28%	30%
0.8	-73%	-62%	-52%	-43%	-35%	-28%	-21%	-15%	-9%	-4%	0%	5%	8%	12%	15%	18%	20%	23%	25%	26%	28%
0.9	-71%	-60%	-51%	-42%	-34%	-27%	-20%	-14%	-9%	-4%	0%	4%	8%	11%	14%	17%	19%	21%	23%	25%	27%
1	-68%	-58%	-49%	-40%	-33%	-26%	-20%	-14%	-9%	-4%	0%	4%	7%	10%	13%	16%	18%	20%	22%	24%	25%
1.1	-66%	-56%	-47%	-39%	-32%	-25%	-19%	-14%	-9%	-4%	0%	3%	7%	10%	13%	15%	17%	19%	21%	23%	24%
1.2	-63%	-54%	-45%	-38%	-31%	-24%	-19%	-13%	-9%	-4%	0%	3%	6%	9%	12%	14%	16%	18%	20%	22%	23%
1.3	-61%	-52%	-44%	-37%	-30%	-24%	-18%	-13%	-9%	-4%	-1%	3%	6%	9%	11%	13%	15%	17%	19%	20%	22%
1.4	-59%	-50%	-42%	-35%	-29%	-23%	-18%	-13%	-9%	-5%	-1%	2%	5%	8%	10%	13%	15%	16%	18%	19%	21%
1.5	-57%	-49%	-41%	-34%	-28%	-22%	-17%	-13%	-8%	-5%	-1%	2%	5%	7%	10%	12%	14%	15%	17%	18%	20%
1.6	-55%	-47%	-40%	-33%	-27%	-22%	-17%	-12%	-8%	-5%	-1%	2%	4%	7%	9%	11%	13%	14%	16%	17%	18%
1.7	-53%	-45%	-38%	-32%	-26%	-21%	-17%	-12%	-8%	-5%	-2%	1%	4%	6%	8%	10%	12%	14%	15%	16%	17%
1.8	-51%	-44%	-37%	-31%	-26%	-21%	-16%	-12%	-8%	-5%	-2%	1%	3%	6%	8%	9%	11%	13%	14%	15%	16%
1.9	-49%	-42%	-36%	-30%	-25%	-20%	-16%	-12%	-8%	-5%	-2%	0%	3%	5%	7%	9%	10%	12%	13%	14%	15%
2	-48%	-41%	-35%	-29%	-24%	-20%	-16%	-12%	-8%	-5%	-3%	0%	2%	4%	6%	8%	10%	11%	12%	13%	14%

Table. 8 SPR (as % of maximum obtainable) of bigeye tuna with various modifiers on the fishing mortality of the FAD and "other" fleets. The current level of fishing mortality is indicated by the circle.

Multiplier on Fishing Effort by FAD Fleets	Multiplier on Fishing Effort by Other Fleets																				
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	100%	94%	88%	83%	79%	74%	70%	66%	63%	59%	56%	53%	51%	48%	46%	44%	41%	39%	38%	36%	34%
0.1	96%	90%	85%	80%	76%	71%	67%	64%	60%	57%	54%	51%	49%	46%	44%	42%	40%	38%	36%	35%	33%
0.2	92%	87%	82%	77%	73%	68%	65%	61%	58%	55%	52%	49%	47%	44%	42%	40%	38%	36%	35%	33%	32%
0.3	89%	83%	78%	74%	70%	66%	62%	59%	56%	53%	50%	47%	45%	43%	41%	39%	37%	35%	33%	32%	30%
0.4	85%	80%	75%	71%	67%	63%	60%	56%	53%	51%	48%	45%	43%	41%	39%	37%	35%	34%	32%	31%	29%
0.5	82%	77%	72%	68%	64%	61%	57%	54%	51%	49%	46%	44%	41%	39%	37%	36%	34%	32%	31%	29%	28%
0.6	79%	74%	70%	66%	62%	58%	55%	52%	49%	47%	44%	42%	40%	38%	36%	34%	33%	31%	30%	28%	27%
0.7	75%	71%	67%	63%	59%	56%	53%	50%	47%	45%	42%	40%	38%	36%	35%	33%	31%	30%	28%	27%	26%
0.8	73%	68%	64%	60%	57%	54%	51%	48%	45%	43%	41%	39%	37%	35%	33%	32%	30%	29%	27%	26%	25%
0.9	70%	66%	62%	58%	55%	52%	49%	46%	44%	41%	39%	37%	35%	34%	32%	30%	29%	28%	26%	25%	24%
1	67%	63%	59%	56%	53%	50%	47%	44%	42%	40%	38%	36%	34%	32%	31%	29%	28%	26%	25%	24%	23%
1.1	64%	60%	57%	54%	51%	48%	45%	43%	40%	38%	36%	34%	33%	31%	29%	28%	27%	25%	24%	23%	22%
1.2	62%	58%	55%	51%	49%	46%	43%	41%	39%	37%	35%	33%	31%	30%	28%	27%	26%	24%	23%	22%	21%
1.3	59%	56%	53%	49%	47%	44%	42%	39%	37%	35%	33%	32%	30%	29%	27%	26%	25%	23%	22%	21%	20%
1.4	57%	54%	50%	48%	45%	42%	40%	38%	36%	34%	32%	30%	29%	27%	26%	25%	24%	23%	21%	20%	20%
1.5	55%	51%	48%	46%	43%	41%	38%	36%	34%	32%	31%	29%	28%	26%	25%	24%	23%	22%	21%	20%	19%
1.6	53%	49%	47%	44%	41%	39%	37%	35%	33%	31%	30%	28%	27%	25%	24%	23%	22%	21%	20%	19%	18%
1.7	51%	48%	45%	42%	40%	37%	35%	33%	32%	30%	28%	27%	26%	24%	23%	22%	21%	20%	19%	18%	17%
1.8	49%	46%	43%	40%	38%	36%	34%	32%	30%	29%	27%	26%	25%	23%	22%	21%	20%	19%	18%	17%	17%
1.9	47%	44%	41%	39%	37%	35%	33%	31%	29%	28%	26%	25%	24%	22%	21%	20%	19%	18%	18%	17%	16%
2	45%	42%	40%	37%	35%	33%	31%	30%	28%	27%	25%	24%	23%	22%	20%	19%	19%	18%	17%	16%	15%

Table. 9 Percent change in YPR of bigeye tuna with various modifiers on the fishing mortality of the “surface” and “other” fleets. The current level of fishing mortality is indicated by the circle.

	Multiplier on Fishing Effort by Other Fleets																				
Multiplier on Fishing Effort by Surface Fleets	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	-100%	-85%	-72%	-60%	-49%	-39%	-30%	-21%	-14%	-7%	0%	5%	11%	15%	20%	24%	27%	31%	34%	36%	39%
0.1	-96%	-82%	-69%	-57%	-47%	-37%	-28%	-20%	-13%	-6%	0%	5%	10%	15%	19%	23%	26%	29%	32%	35%	37%
0.2	-91%	-78%	-66%	-55%	-45%	-35%	-27%	-19%	-12%	-6%	0%	5%	10%	14%	18%	22%	25%	28%	31%	33%	36%
0.3	-87%	-75%	-63%	-52%	-43%	-34%	-26%	-18%	-12%	-5%	0%	5%	10%	14%	18%	21%	24%	27%	30%	32%	34%
0.4	-84%	-71%	-60%	-50%	-41%	-32%	-24%	-17%	-11%	-5%	0%	5%	9%	13%	17%	20%	23%	26%	28%	31%	33%
0.5	-80%	-68%	-57%	-48%	-39%	-31%	-23%	-17%	-11%	-5%	0%	5%	9%	13%	16%	19%	22%	25%	27%	29%	31%
0.6	-76%	-65%	-55%	-46%	-37%	-29%	-22%	-16%	-10%	-5%	0%	5%	9%	12%	16%	19%	21%	24%	26%	28%	30%
0.7	-73%	-62%	-53%	-44%	-36%	-28%	-21%	-15%	-10%	-4%	0%	4%	8%	12%	15%	18%	20%	23%	25%	27%	29%
0.8	-70%	-60%	-50%	-42%	-34%	-27%	-20%	-15%	-9%	-4%	0%	4%	8%	11%	14%	17%	20%	22%	24%	26%	27%
0.9	-67%	-57%	-48%	-40%	-33%	-26%	-20%	-14%	-9%	-4%	0%	4%	7%	11%	14%	16%	19%	21%	23%	25%	26%
1	-64%	-55%	-46%	-38%	-31%	-25%	-19%	-13%	-9%	-4%	0%	4%	7%	10%	13%	15%	18%	20%	22%	23%	25%
1.1	-62%	-53%	-44%	-37%	-30%	-24%	-18%	-13%	-8%	-4%	0%	3%	7%	10%	12%	15%	17%	19%	21%	22%	24%
1.2	-59%	-50%	-43%	-35%	-29%	-23%	-17%	-13%	-8%	-4%	0%	3%	6%	9%	12%	14%	16%	18%	20%	21%	23%
1.3	-57%	-48%	-41%	-34%	-28%	-22%	-17%	-12%	-8%	-4%	0%	3%	6%	9%	11%	13%	15%	17%	19%	20%	21%
1.4	-54%	-46%	-39%	-33%	-27%	-21%	-16%	-12%	-8%	-4%	0%	3%	5%	8%	10%	12%	14%	16%	18%	19%	20%
1.5	-52%	-45%	-38%	-31%	-26%	-20%	-16%	-11%	-7%	-4%	-1%	2%	5%	8%	10%	12%	14%	15%	17%	18%	19%
1.6	-50%	-43%	-36%	-30%	-25%	-20%	-15%	-11%	-7%	-4%	-1%	2%	5%	7%	9%	11%	13%	14%	16%	17%	18%
1.7	-48%	-41%	-35%	-29%	-24%	-19%	-15%	-11%	-7%	-4%	-1%	2%	4%	6%	9%	10%	12%	14%	15%	16%	17%
1.8	-46%	-40%	-34%	-28%	-23%	-19%	-14%	-11%	-7%	-4%	-1%	1%	4%	6%	8%	10%	11%	13%	14%	15%	16%
1.9	-45%	-38%	-32%	-27%	-22%	-18%	-14%	-10%	-7%	-4%	-1%	1%	3%	5%	7%	9%	11%	12%	13%	14%	15%
2	-43%	-37%	-31%	-26%	-22%	-17%	-14%	-10%	-7%	-4%	-2%	1%	3%	5%	7%	8%	10%	11%	12%	13%	14%

Table. 10 SPR (as % of maximum obtainable) of bigeye tuna with various modifiers on the fishing mortality of the “surface” and “other” fleets. The current level of fishing mortality is indicated by the circle.

	Multiplier on Fishing Effort by Other Fleets																				
Multiplier on Fishing Effort by Surface Fleets	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
0	100%	94%	89%	84%	79%	75%	71%	67%	64%	60%	57%	55%	52%	49%	47%	45%	43%	41%	39%	37%	36%
0.1	96%	90%	85%	80%	76%	72%	68%	64%	61%	58%	55%	52%	50%	47%	45%	43%	41%	39%	37%	36%	34%
0.2	92%	87%	82%	77%	73%	69%	65%	62%	59%	56%	53%	50%	48%	45%	43%	41%	39%	37%	36%	34%	33%
0.3	88%	83%	78%	74%	70%	66%	63%	59%	56%	53%	51%	48%	46%	43%	41%	39%	38%	36%	34%	33%	31%
0.4	84%	80%	75%	71%	67%	63%	60%	57%	54%	51%	48%	46%	44%	42%	40%	38%	36%	34%	33%	31%	30%
0.5	81%	76%	72%	68%	64%	61%	57%	54%	52%	49%	46%	44%	42%	40%	38%	36%	35%	33%	32%	30%	29%
0.6	78%	73%	69%	65%	62%	58%	55%	52%	49%	47%	45%	42%	40%	38%	37%	35%	33%	32%	30%	29%	28%
0.7	74%	70%	66%	62%	59%	56%	53%	50%	47%	45%	43%	41%	39%	37%	35%	33%	32%	30%	29%	28%	27%
0.8	71%	67%	63%	60%	57%	53%	51%	48%	45%	43%	41%	39%	37%	35%	34%	32%	31%	29%	28%	27%	25%
0.9	68%	64%	61%	57%	54%	51%	49%	46%	44%	41%	39%	37%	35%	34%	32%	31%	29%	28%	27%	25%	24%
1	65%	62%	58%	55%	52%	49%	47%	44%	42%	40%	38%	36%	34%	32%	31%	29%	28%	27%	26%	24%	23%
1.1	63%	59%	56%	53%	50%	47%	45%	42%	40%	38%	36%	34%	33%	31%	30%	28%	27%	26%	25%	23%	22%
1.2	60%	57%	53%	50%	48%	45%	43%	40%	38%	36%	35%	33%	31%	30%	28%	27%	26%	25%	24%	22%	21%
1.3	58%	54%	51%	48%	46%	43%	41%	39%	37%	35%	33%	32%	30%	29%	27%	26%	25%	24%	23%	22%	21%
1.4	55%	52%	49%	46%	44%	41%	39%	37%	35%	33%	32%	30%	29%	27%	26%	25%	24%	23%	22%	21%	20%
1.5	53%	50%	47%	44%	42%	40%	38%	36%	34%	32%	30%	29%	28%	26%	25%	24%	23%	22%	21%	20%	19%
1.6	51%	48%	45%	43%	40%	38%	36%	34%	32%	31%	29%	28%	26%	25%	24%	23%	22%	21%	20%	19%	18%
1.7	49%	46%	43%	41%	39%	37%	35%	33%	31%	30%	28%	27%	25%	24%	23%	22%	21%	20%	19%	18%	17%
1.8	47%	44%	41%	39%	37%	35%	33%	31%	30%	28%	27%	26%	24%	23%	22%	21%	20%	19%	18%	17%	17%
1.9	45%	42%	40%	38%	35%	34%	32%	30%	29%	27%	26%	24%	23%	22%	21%	20%	19%	18%	18%	17%	16%
2	43%	40%	38%	36%	34%	32%	30%	29%	27%	26%	25%	23%	22%	21%	20%	19%	18%	18%	17%	16%	15%

Table 11. Landings by species (t) during 2005-2007 for the purse-seine European (and associated flags) fishing fleet. YFT = yellowfin, SKJ = skipjack, BET = bigeye.

Year	*YFT*	*SKJ*	*BET*	*Others*	*TOTAL*
2005	49,456	59,630	9,835	2,189	121,110
2006	51,186	49,169	11,077	1,720	113,152
2007	43,183	54,178	10,794	2,017	110,172

Table 12. Landings by species (t) during 2005-2007 for the tropical bait boat European fishing fleet. YFT = yellowfin, SKJ = skipjack, BET = bigeye.

Year	*YFT*	*SKJ*	*BET*	*Others*	*TOTAL*
2005	2,160	15,089	2,326	162	19,737
2006	2,215	9,349	2,733	1,319	15,616
2007	1,658	11,382	2,225	1,553	16,818

Table 13 Catch (t) and percentage contribution of principal tunas species by the Ghanaian fishery.

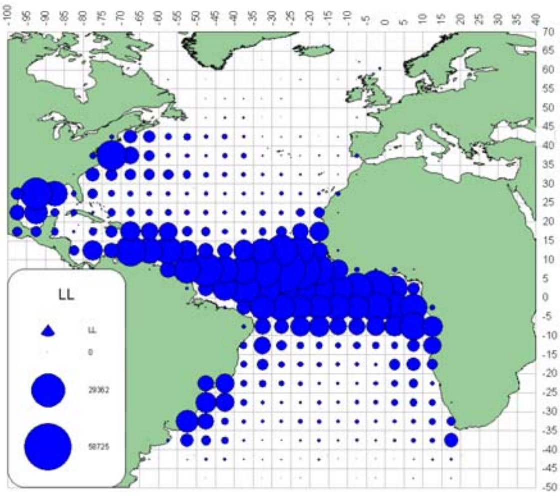
Year	*Bigeye*	*Skipjack*	*Yellowfin*	*Total*	*% Bigeye*	*% Skipjack*	*% Yellowfin*
1997	9,758	26,035	15,809	51,602	18.91	50.45	30.64
1998	13,423	33,941	17,846	65,210	20.58	52.05	27.37
1999	17,763	40,217	25,268	83,248	21.34	48.31	30.35
2000	5,910	28,974	17,662	52,546	11.25	55.14	33.61
2001	12,041	42,489	33,546	88,076	13.67	48.24	38.09
2002	7,106	30,499	23,675	61,280	11.60	49.77	38.63
2003	13,557	24,597	18,457	56,611	23.95	43.45	32.60
2004	14,901	25,726	15,054	55,681	26.76	46.20	27.04
2005	13,916	44,671	17,493	76,080	18.29	58.72	22.99
2006	9,141	30,236	11,931	51,308	17.82	58.93	23.25
2007	4,633	45,709	12,954	63,296	7.32	72.21	20.47
2008	9,269	37,387	14,250	60,906	14.64	59.07	22.51

Table 14 Total annual catches (t) of the four vessels (2 BB and 2 PS) participating in the Ghanaian observer program in 2008.

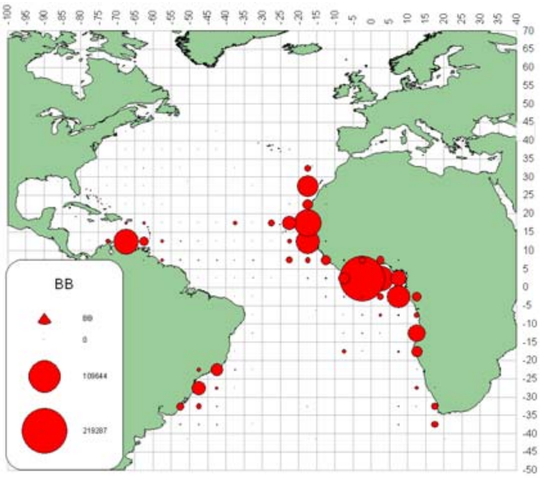
		Yellowfin	*Bigeye*	*Skipjack*	*Others*	*Total*
AFKO 801	BB	55.1	7.1	127.7	21.2	211.1
LAURENT	PS	70.0	19.0	190.0	5.5	284.5
RICOUNO	BB	74.6	12.69	126.8	0.4	214.49
AGNES	PS	226.9	43.6	538.9	61.2	870.6
Total		426.6	82.39	983.4	88.3	1580.69
Percent		26.98	5.21	62.21	5.58	100

Table 15. Estimations préliminaires des débarquements (t) par espèce et engin au cours de la période 2004-2007 pour la pêcherie Cap-Verdienne. HAND = ligne à main ; BB = canneur ; PS = senneur.

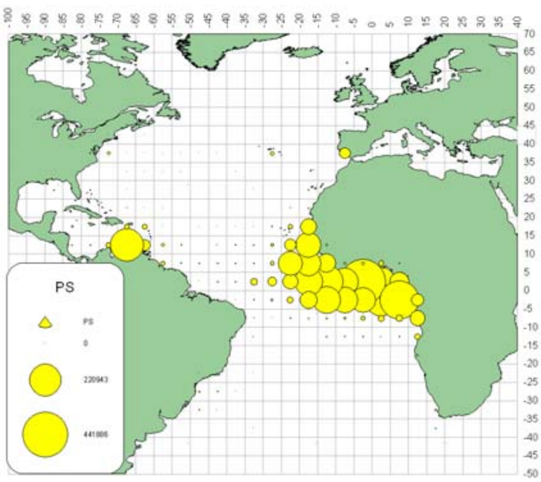
Species	*Gear*	*2004*	*2005*	*2006*	*2007*
BET	HAND	1	0	1	
BET	PS		1092	1436	1147
Cape Verde Total BET		1	1092	1437	1147
YFT	BB	1379			
YFT	HAND	1501	1895	1845	1240
YFT	PS	356	5259	6267	2817
Cape Verde Total YFT		3236	7154	8112	4057
SKJ	BB	57	57	57	
SKJ	PS	1040	7447	7873	6026
Cape Verde Total SKJ		1097	7504	7930	6026
LTA	PS	137	40	160	348
Cape Verde Total LTA		137	40	160	348
WAH	HAND	365	5	503	414
WAH	PS	93	40	34	40
Cape Verde Total WAH		458	45	537	454
FRI	PS	344	167	404	197
Cape Verde Total FRI		344	167	404	197



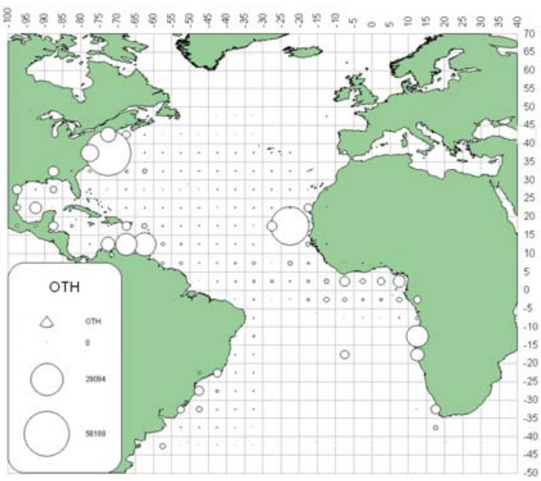
a. YFT (LL)



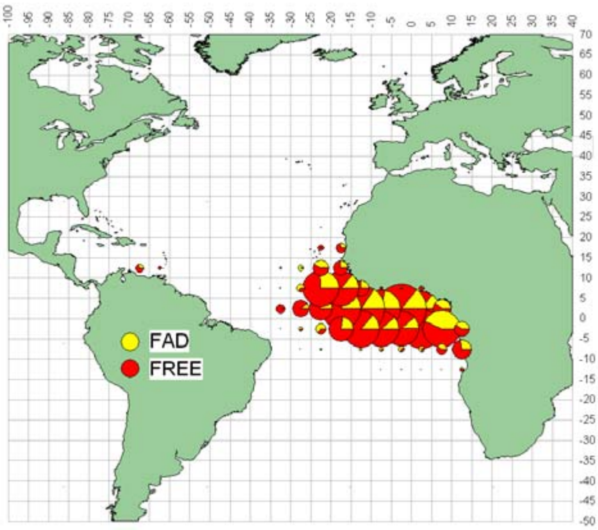
b. YFT (BB)



c. YFT (PS)



d. YFT (OTH)



e. YFT (FAD/FREE 1991-2006

Figure 1. Geographic distribution of yellowfin catches (YFT, *Thunnus albacares*).

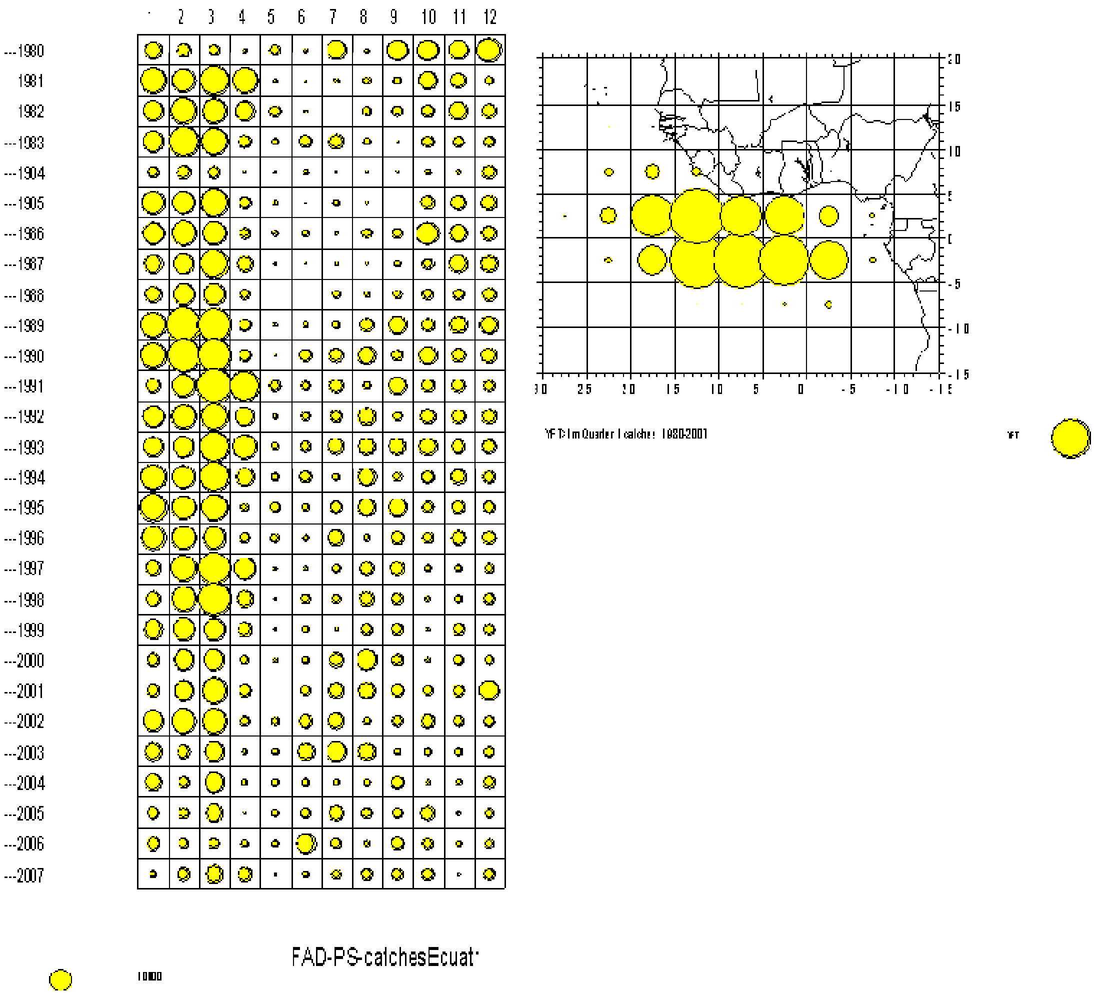


Figure 2. Observed seasonality of the catches of YFT >1 m (Potential spawners) in the Guinea Gulf (left). Average catches of YFT taken at spawning sizes >1m by European and associated PS during the 1 quarter, period 1980-2007 (right).

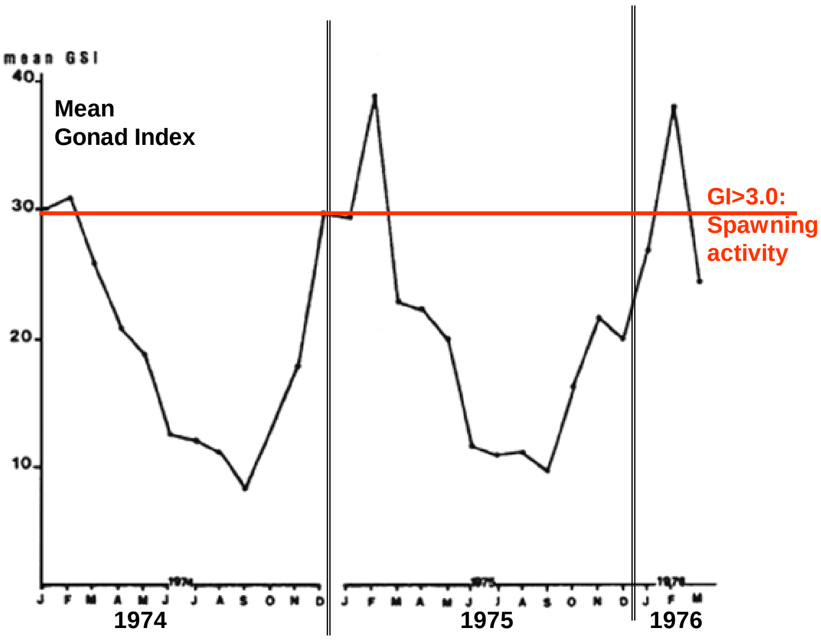


Figure 3. Gonadal index of fish within the Gulf of Guinea. GI levels above 3 are considered to be spawning fully.

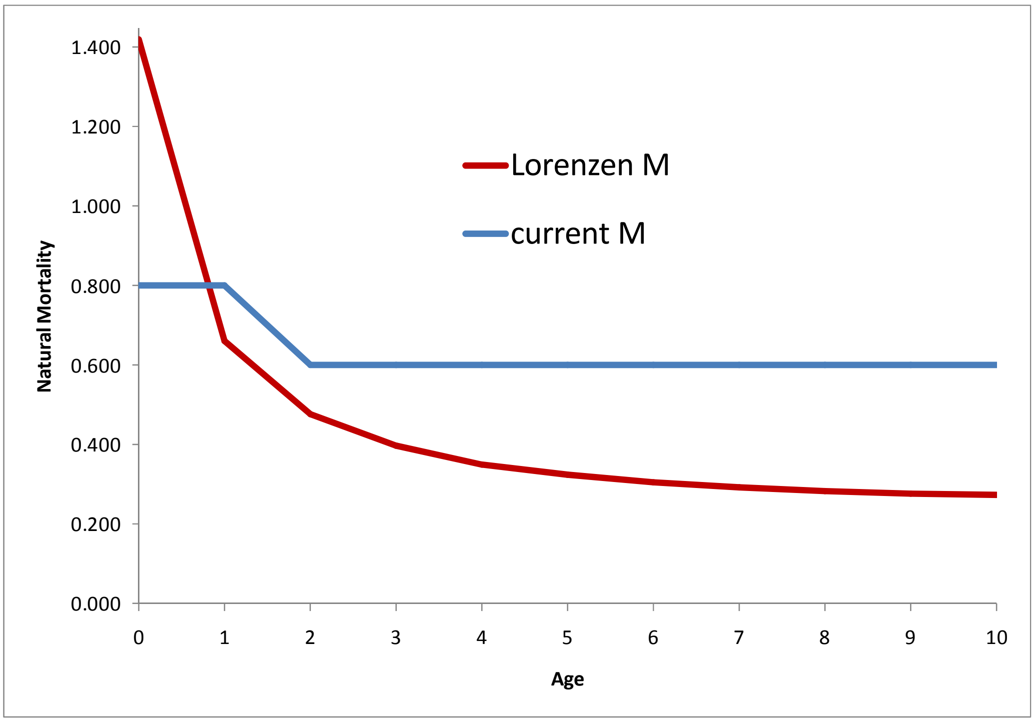


Figure 4. Comparison of the current working hypothesis for the natural mortality (M) vector (in blue) and an alternative Lorenzen M vector.

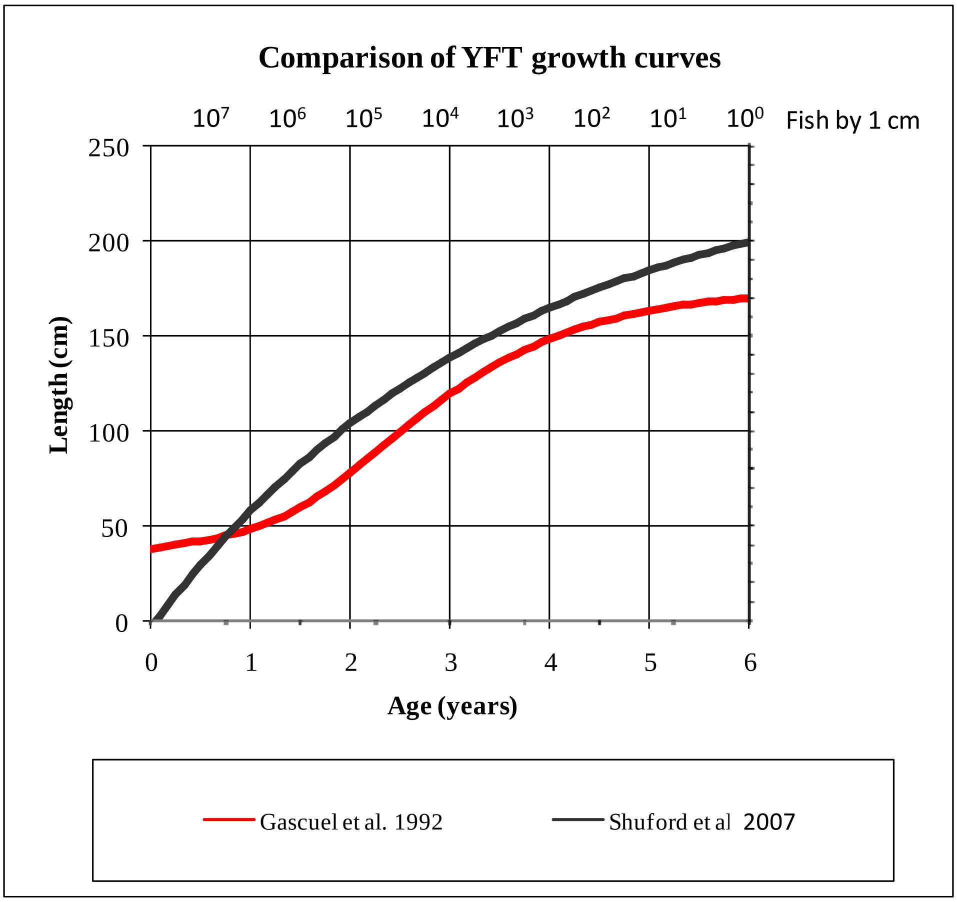


Figure 5. Comparison of the current working hypothesis for YFT growth (Gascuel *et al.* 1992) with one alternative model (Shuford *et al.* 2007). The overall catch-at-size for 1970-2006 is shown, with the number of fish (on a logarithmic scale) displayed on the upper axis.

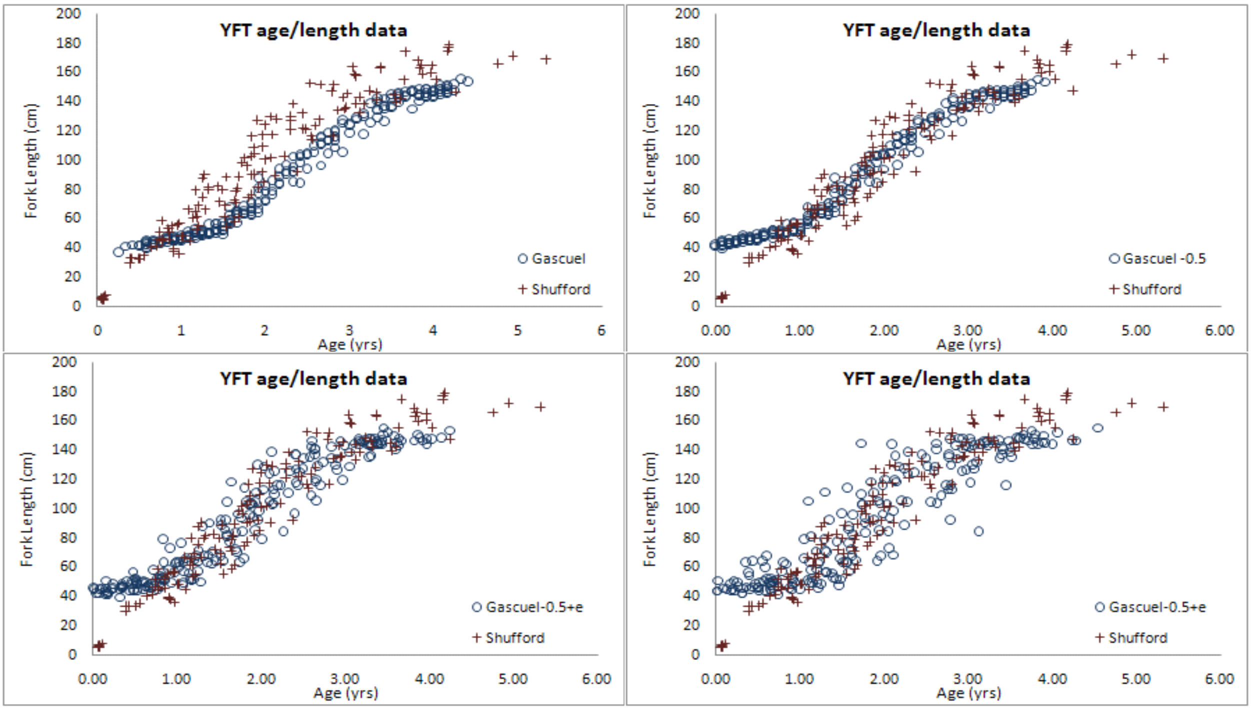


Figure 6. Length-age observations used in two growth studies (Shufford *et al.*, and Gascuel *et al.*). Top left: original data. Top right: Gascuel et al. data set is shifted 0.5 years. Bottom: Gascuel *et al.* data are shifted and a normally distributed error term with mean 0 is added (left: s.d.=0.25; right: s.d.=0.4).

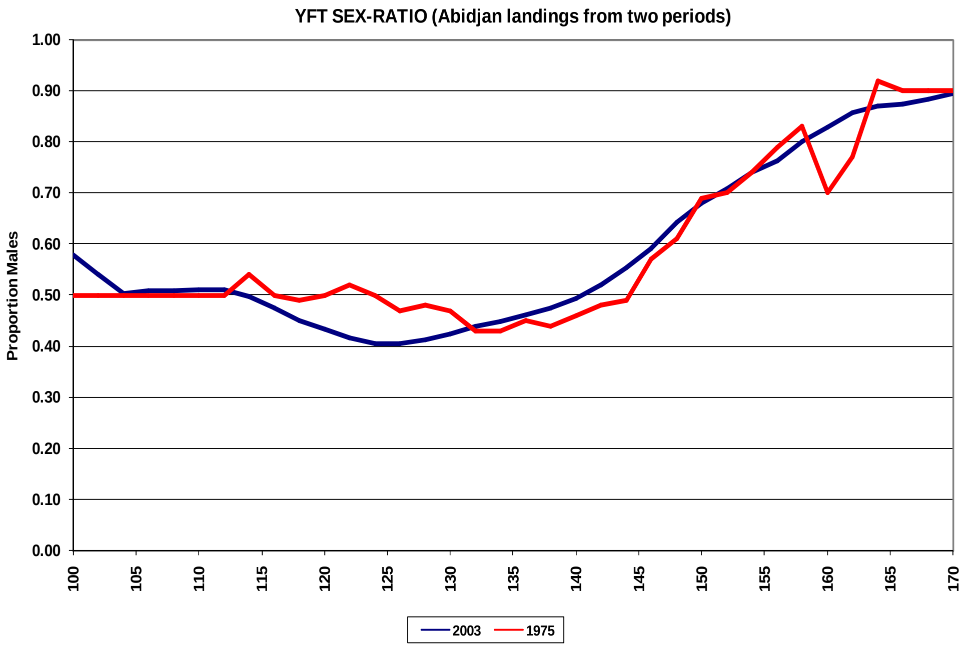


Figure 7. Proportion of YFT catch in Abidjan identified as male, by 2 cm interval. Restricted to fish between 100-170 cm for which sex is identified.

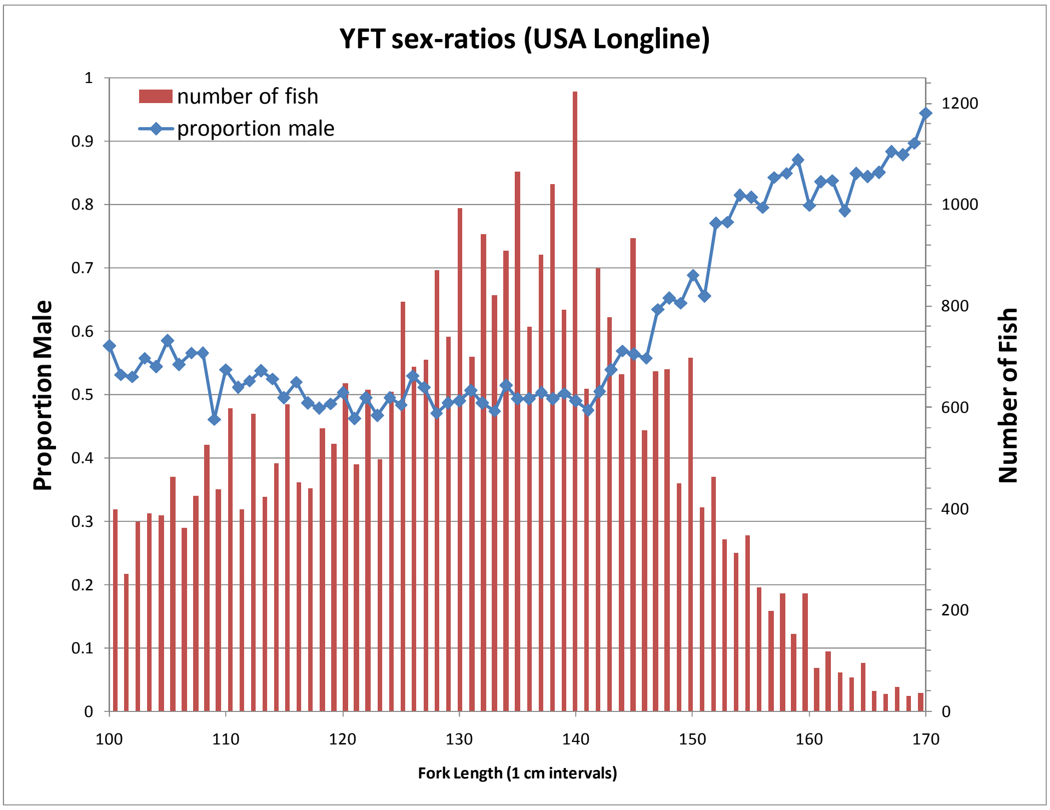


Figure 8. Proportion of USA longline YFT catch identified as male, by 1 cm interval. Restricted to fish between 100-170 cm for which sex is identified.

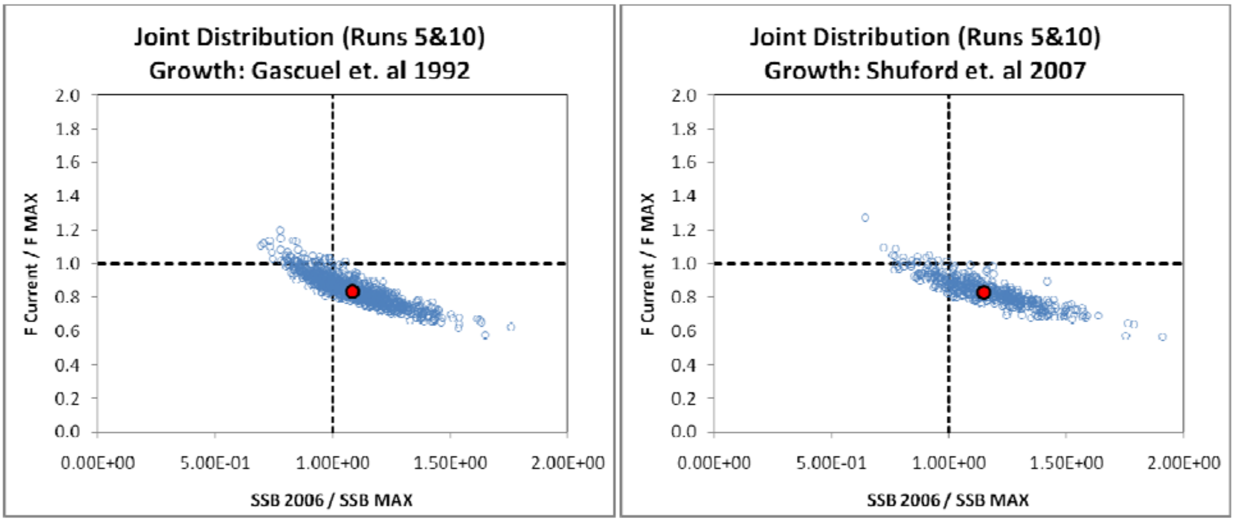


Figure 9. Comparison of stock status reference points and model uncertainty for yellowfin tuna model runs using the Gascuel *et al.* 1992 (2008 Base Results) and Shuford et. al 2007 growth functions.

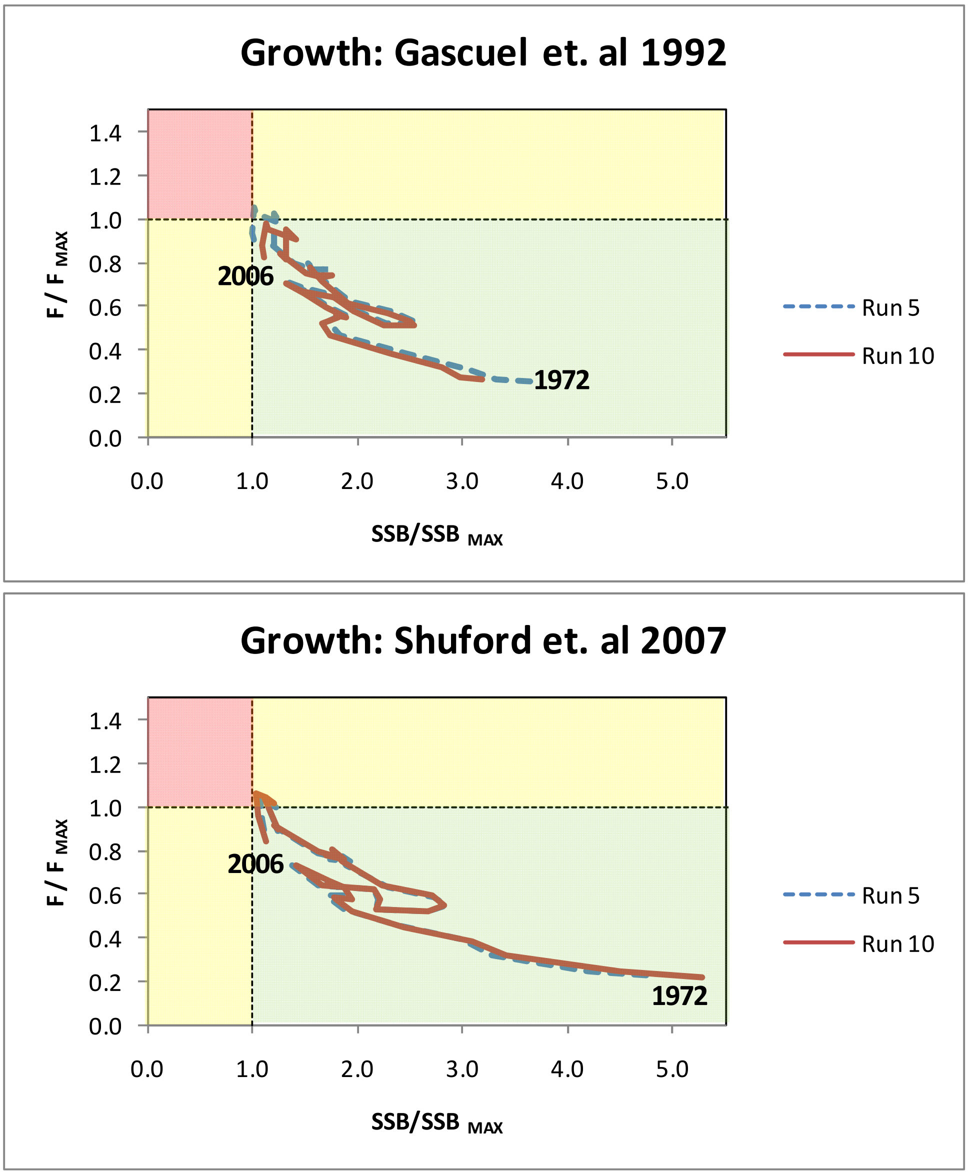
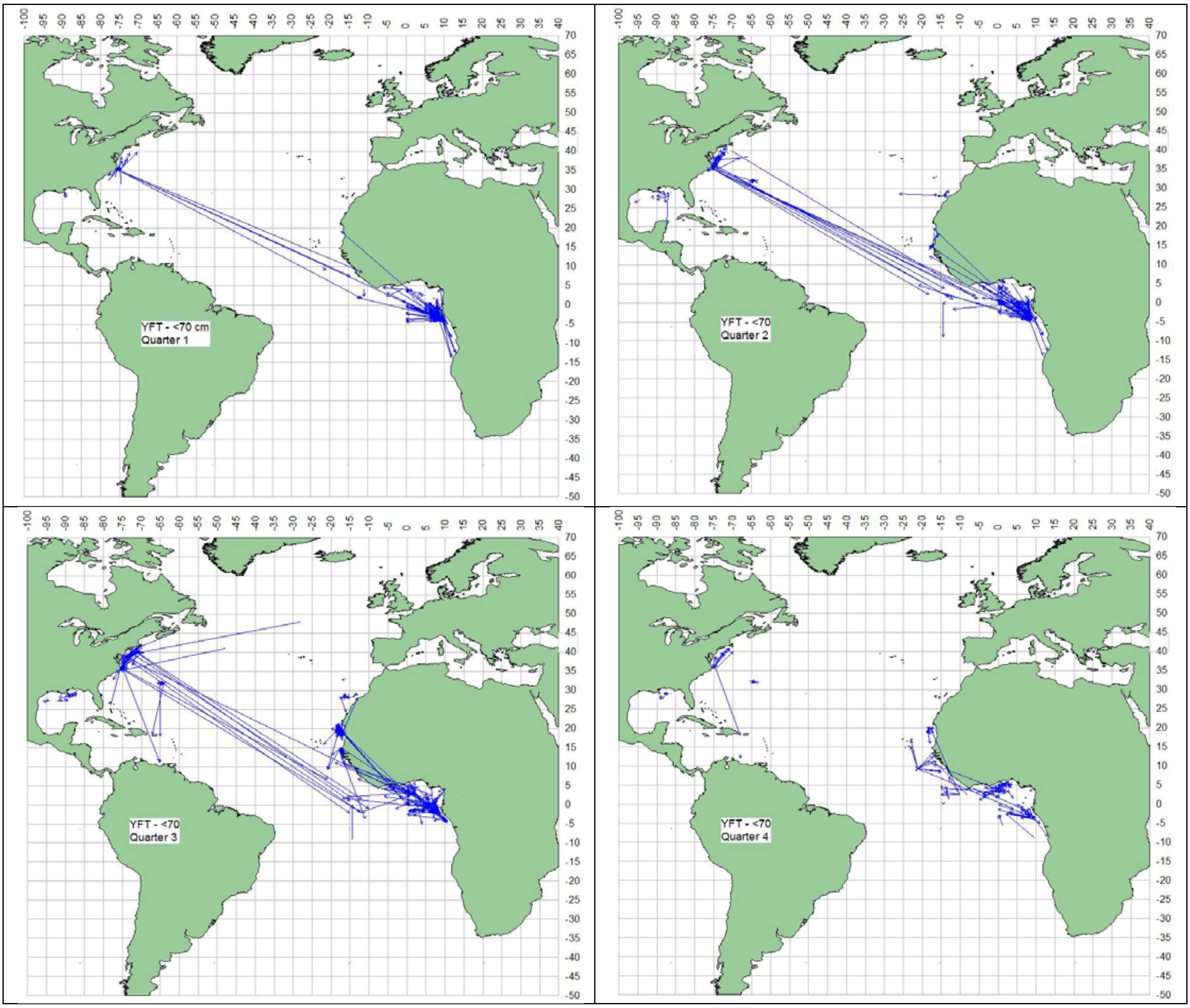
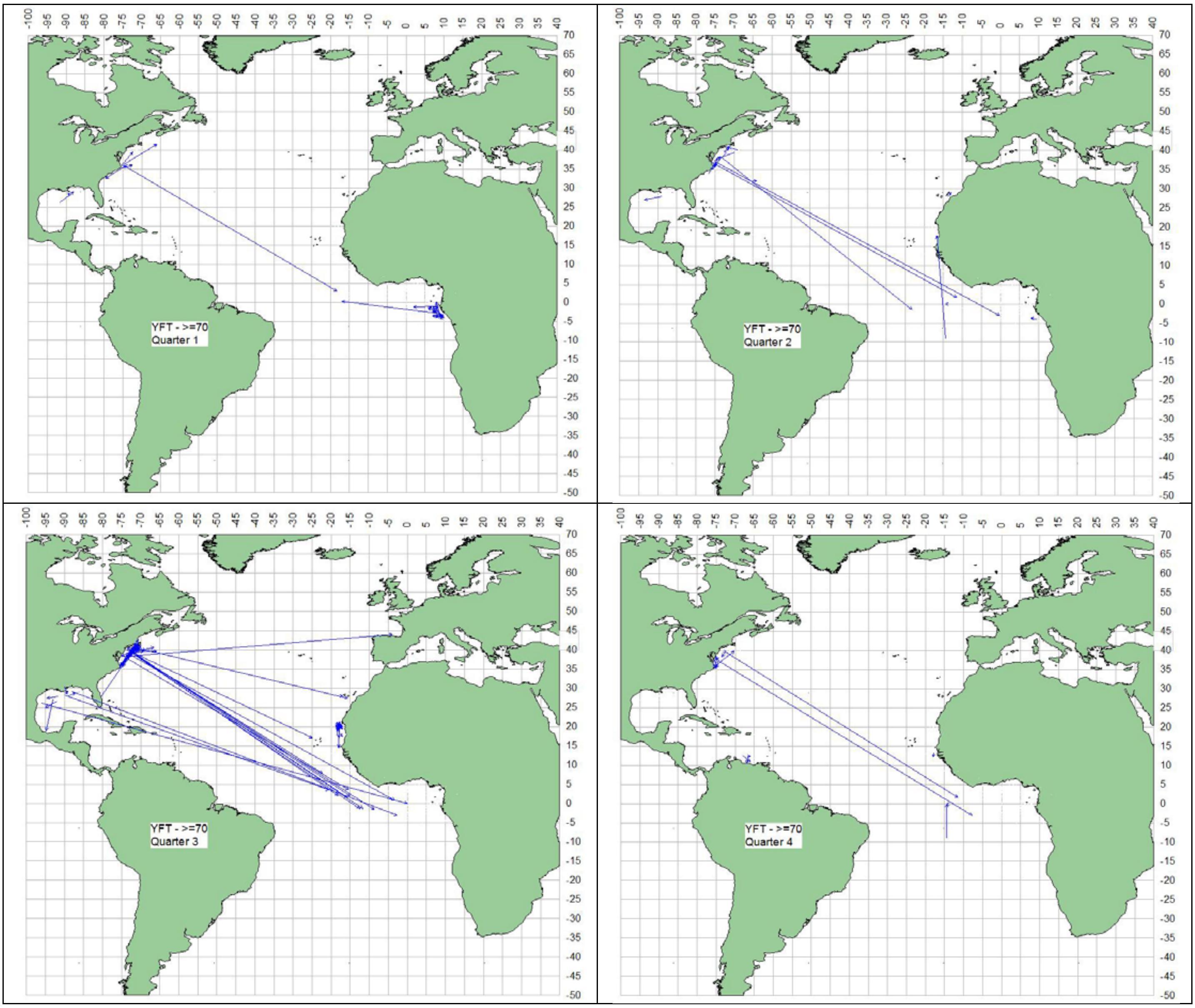


Figure 10. Comparison of stock status trajectories for yellowfin tuna model runs using the Gascuel *et. Al.* 1992 (2008 Base Results) and Shuford et. al 2007 growth functions.

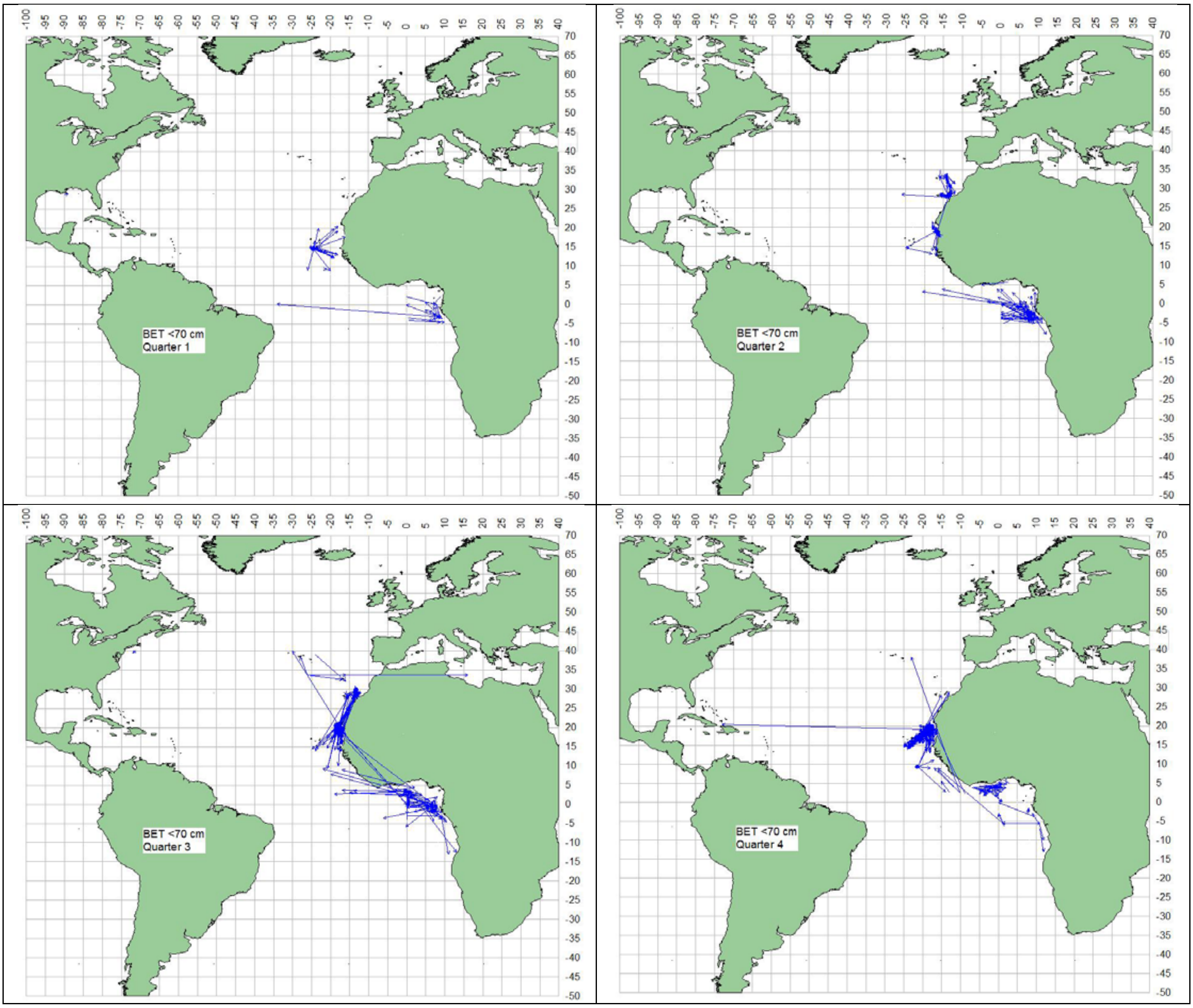
YFT - Less than 70 cm by quarter.



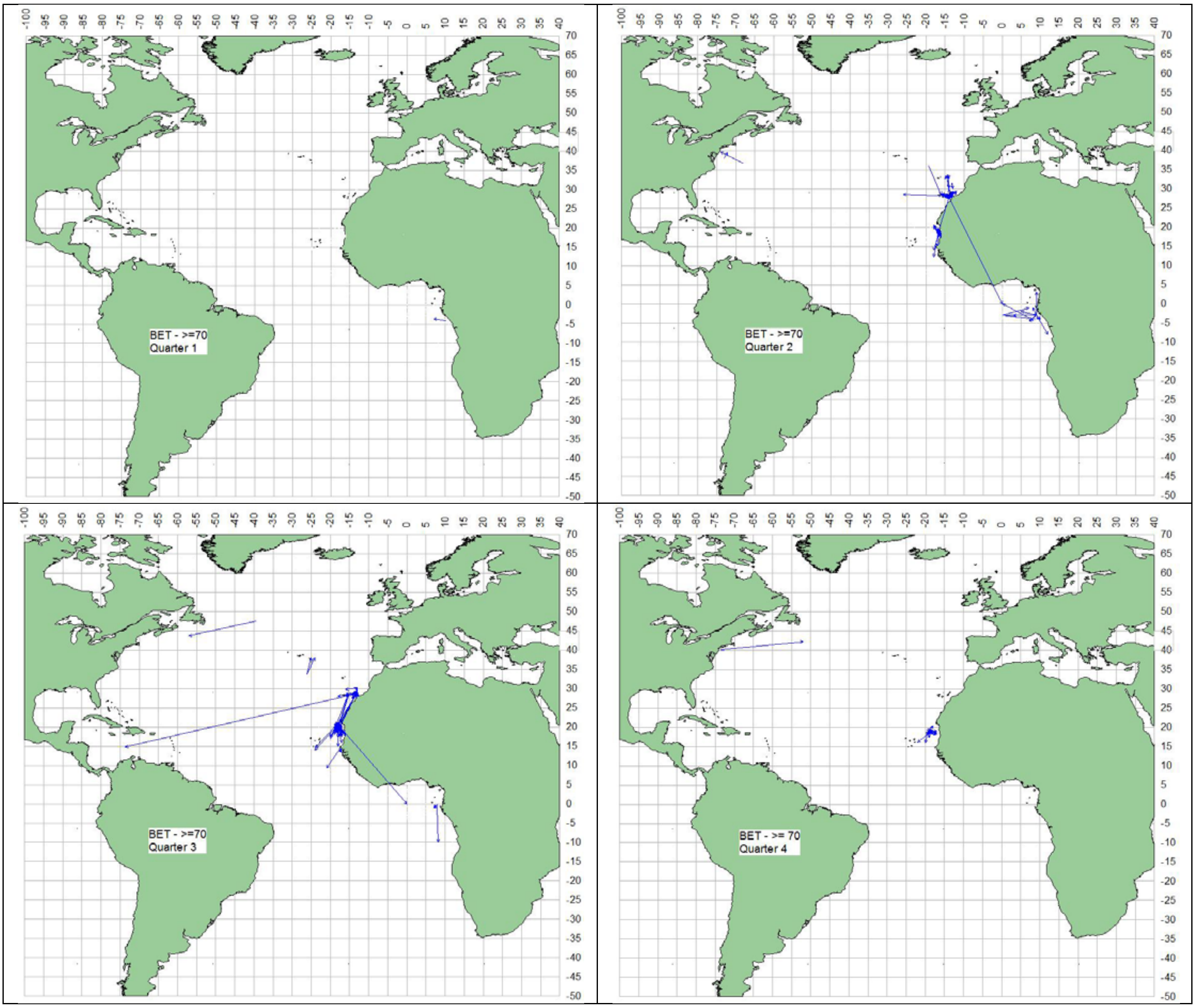
YFT - Greater than or equal to 70 cm by quarter.



BET - Less than 70 cm by quarter.



BET - Greater than or equal to 70 cm by quarter.



SKJ - By quarter.

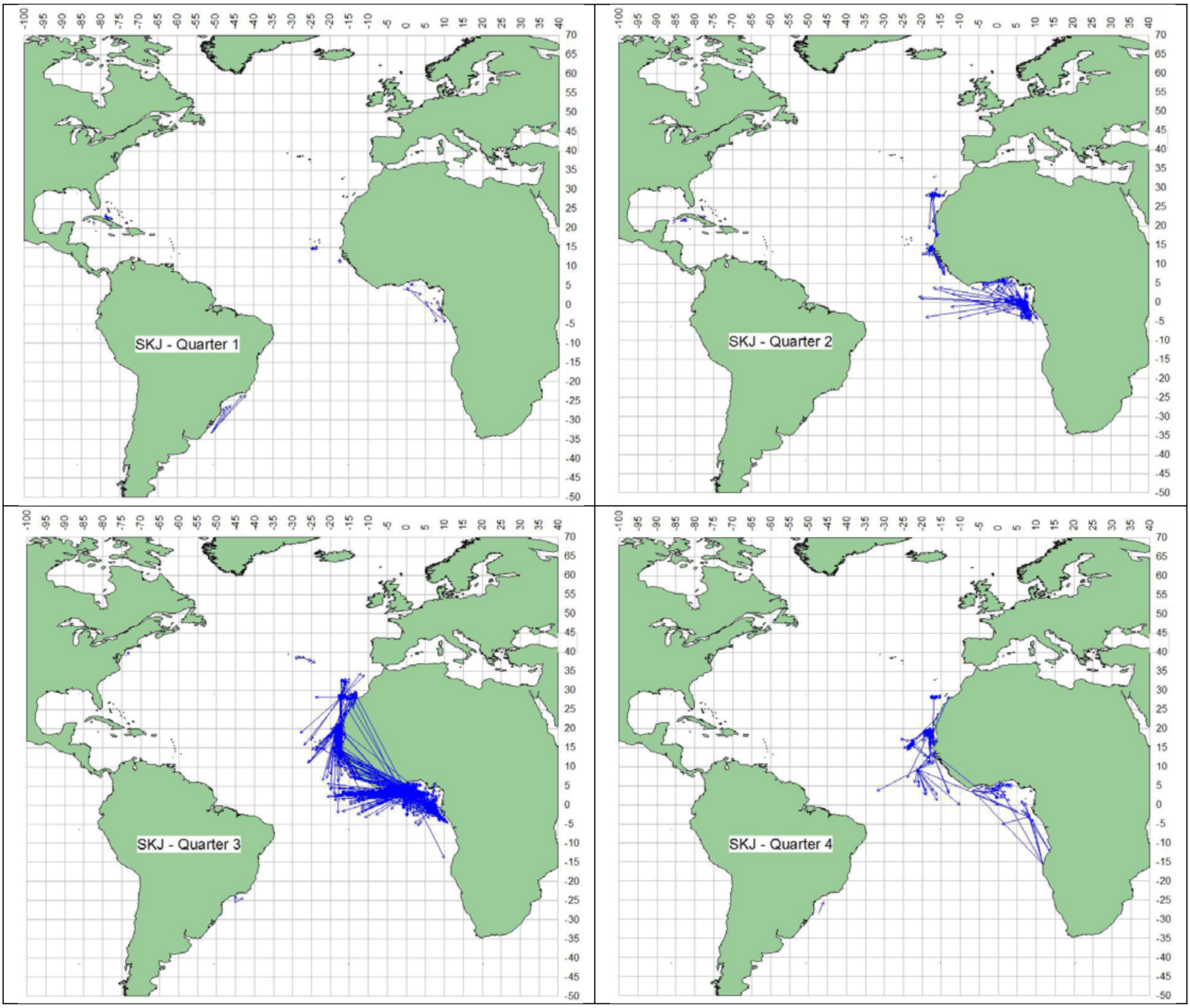


Figure 11. Apparent trajectories of released tuna by size category and by quarters of the year.

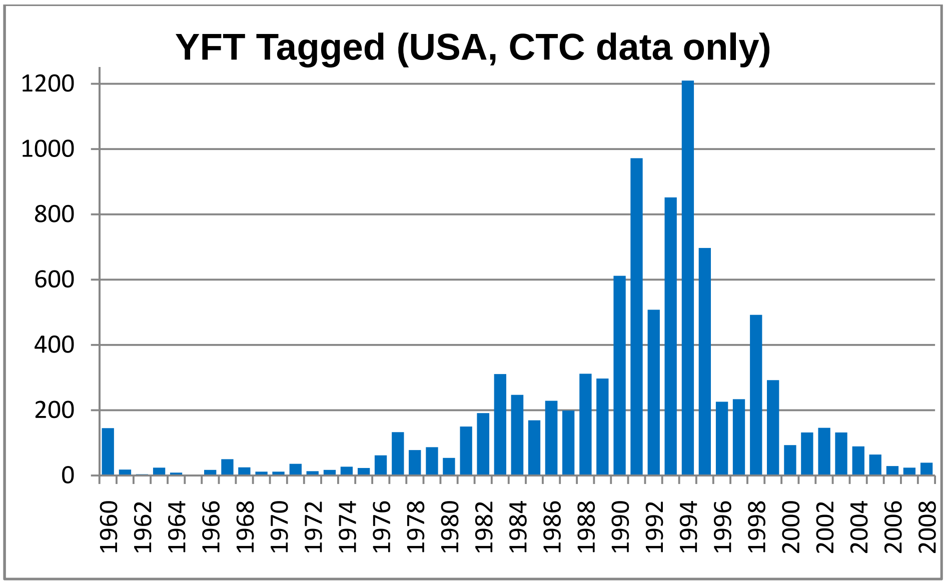


Figure 12. Number of yellowfin released by year in the western Atlantic. Data not shown for other tagging programs, such as The Billfish Foundation. Data for recent years may be incomplete.

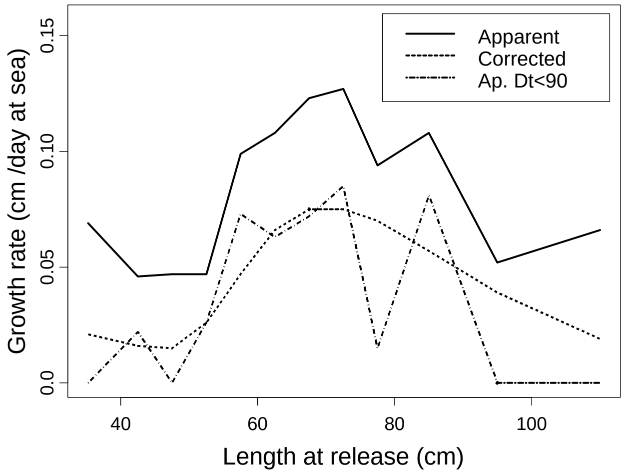


Figure 13. Change in growth rate over length at release for yellowfin from combined tagging data (Atlantic and Indian Oceans). Apparent = observed median growth rate by length class; Ap. Dt<90 = observed median growth rate for time at liberty lower than 90 days at sea; Corrected = predicted growth rate from a GAM assuming one day at liberty.

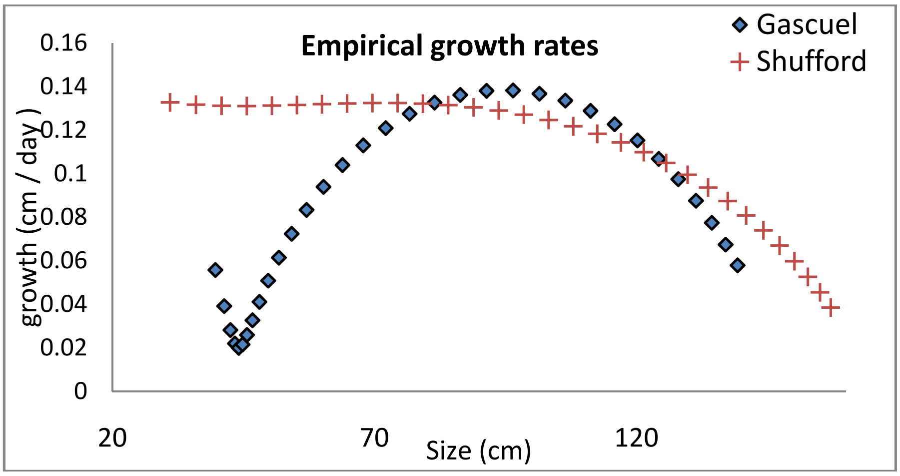


Figure 14. Empirical growth rates of yellowfin estimated for the 5-parameters growth curve by Gascuel *at al*, from tagging data and for the von Bertalanffy curve by Shuford *et al.* from hard part reading.

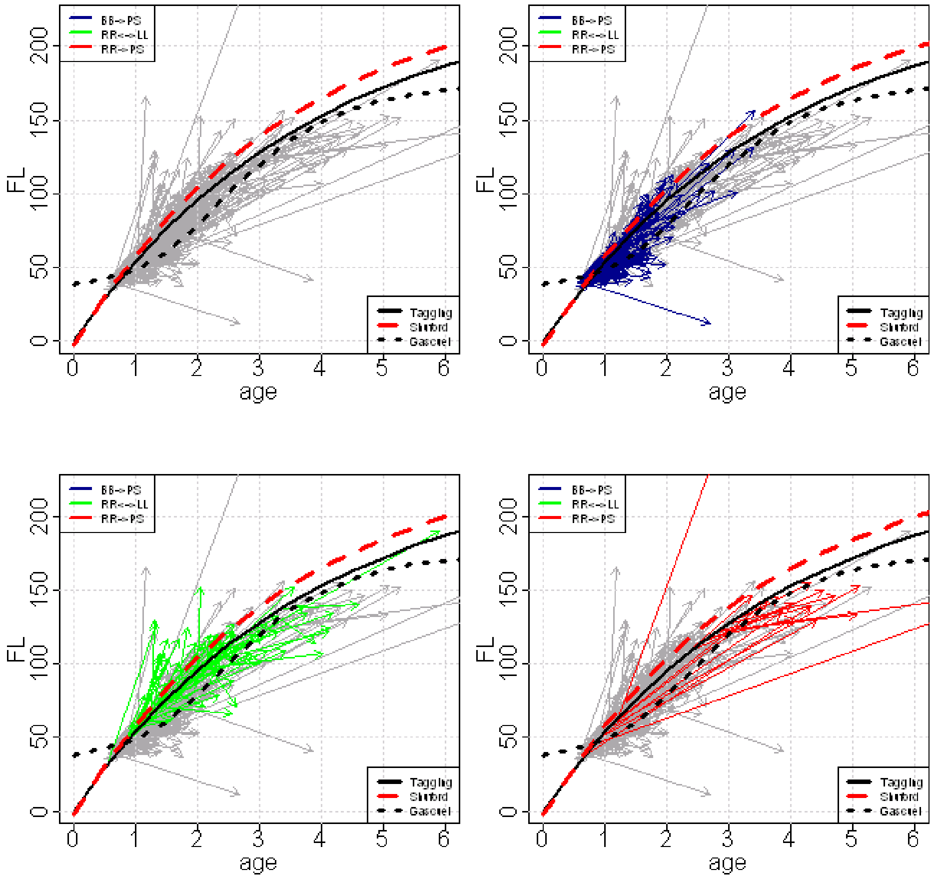


Figure 15. Comparison between growth models (von Bertalanffy vs. 5-parameters two-stanza model) for Atlantic yellowfin. The length at release was arbitrarily superposed on the predicted curve with the aim of showing the dispersion of the length at recapture with respect to the predicted curve.The tagging data were broken down according to the gears at release and at recapture.

A B C

Figure 16. Total monthly catches on FADs taken by EU PS and Ghana (estimated) in three regions: A, B and C. Catches during the FAD moratorium period are indicated by the orange outline.

Figure 17. Average catches on FADs taken by EU PS and Ghana (estimated) in during three time periods**.**

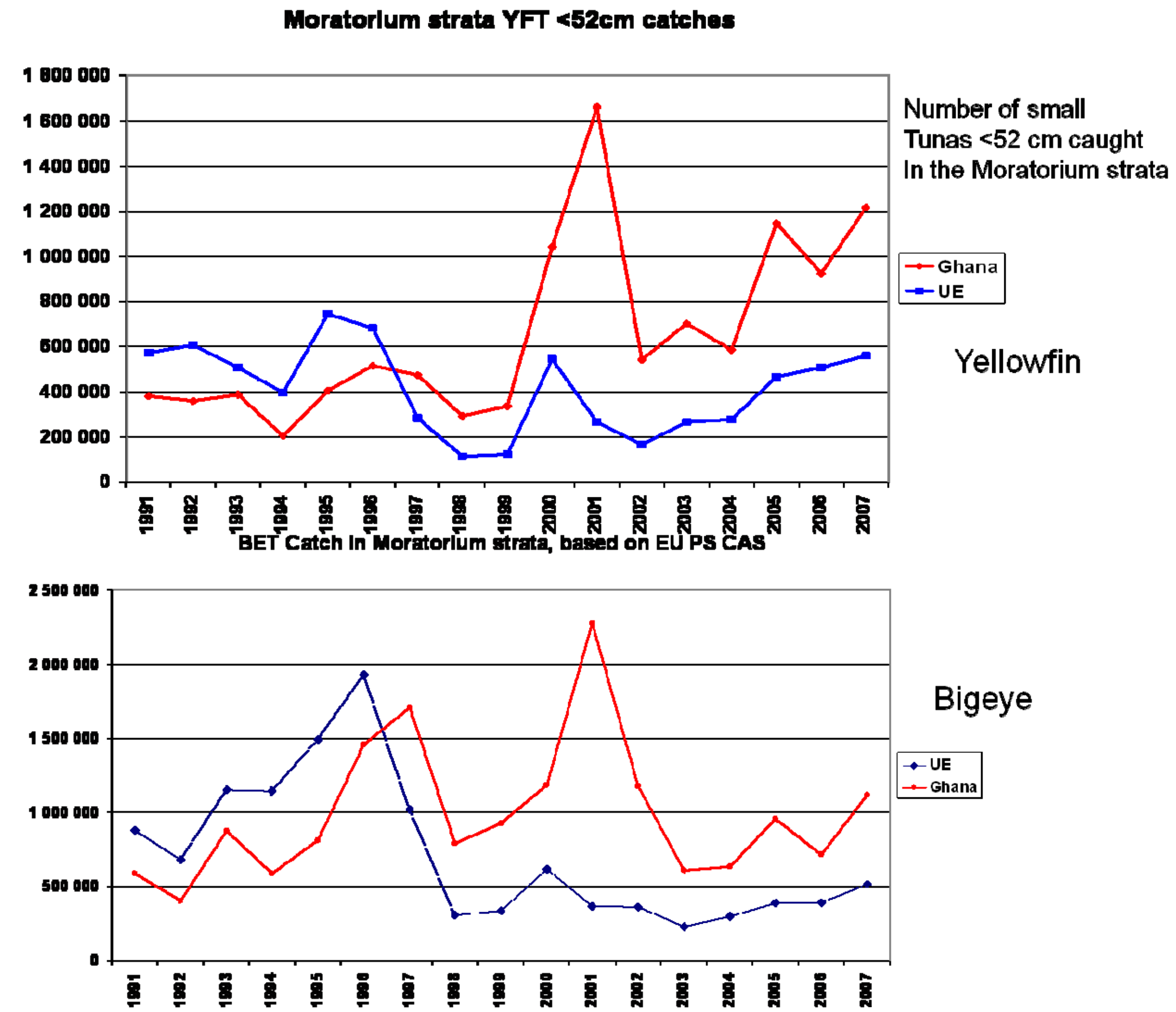
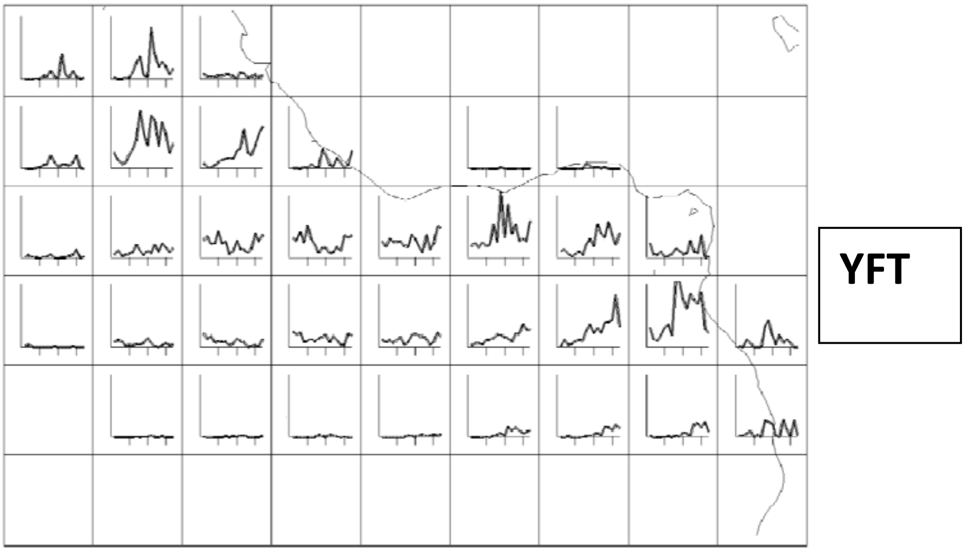


Figure 18. Total annual catches of yellowfin and bigeye (>52cm) within the moratorium region by the EU purse siene and Ghana (estimated).



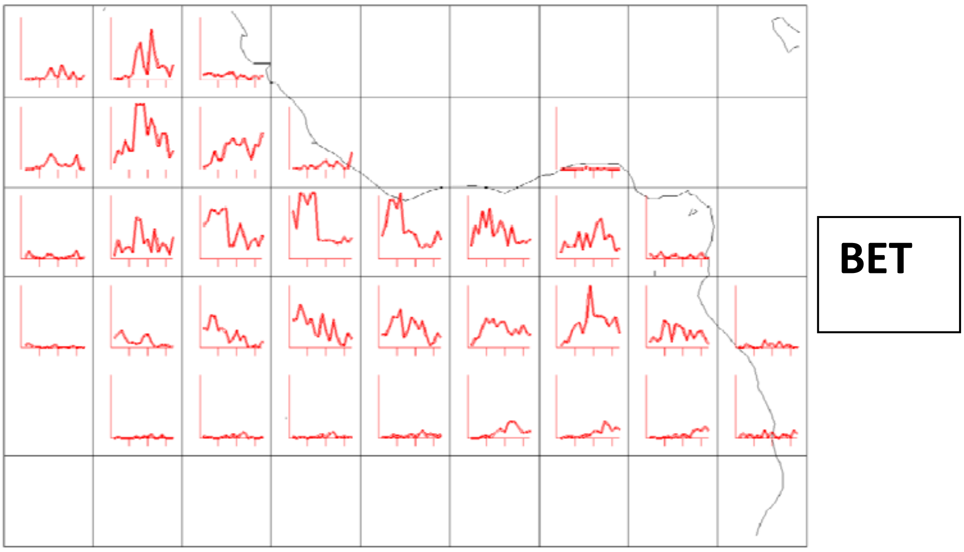


Figure 19. Annual catches of small YFT and BET (< 60cm) by EU and Ghana (estimated) of during 1991-2007.

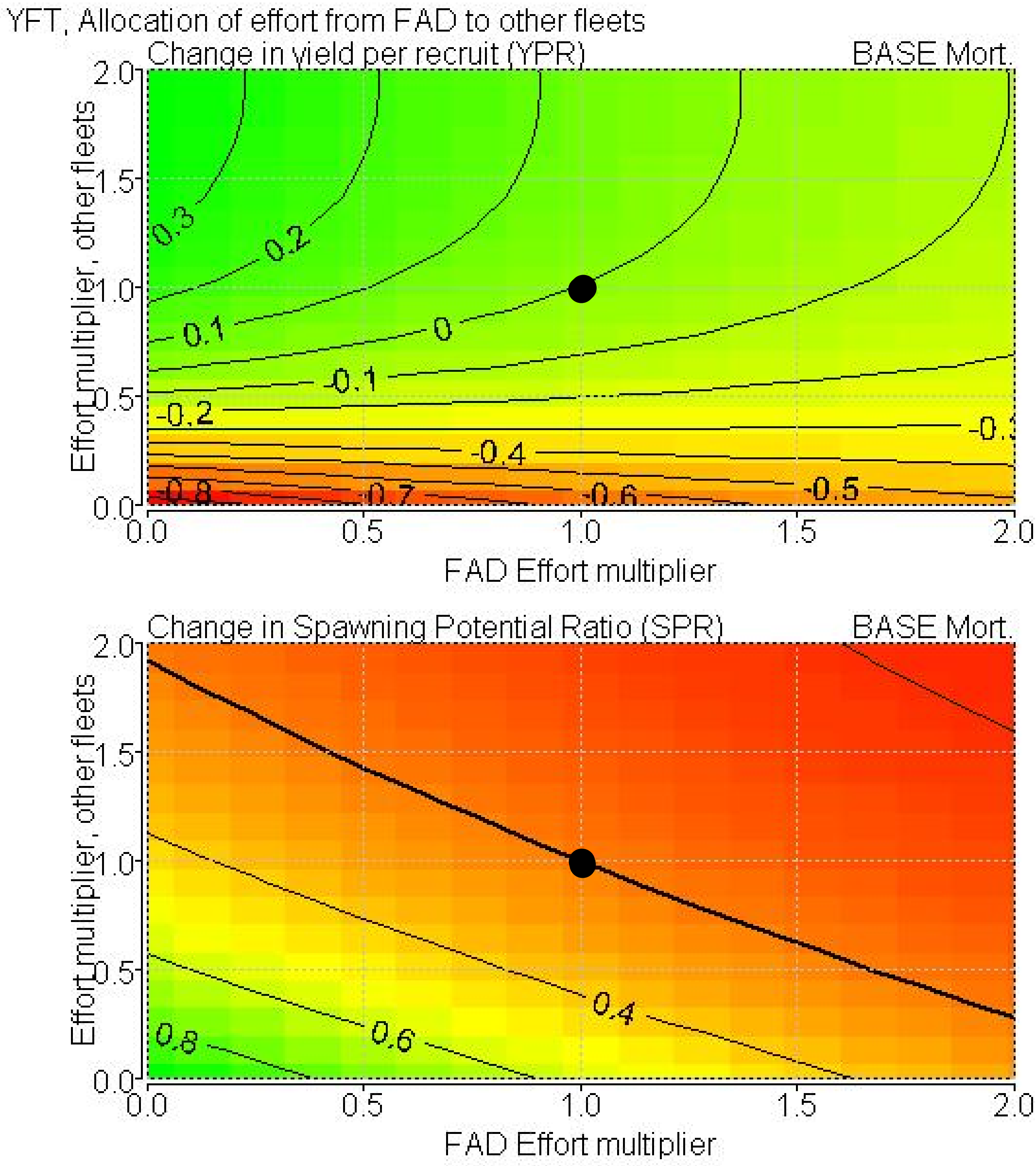


Figure 20. Percent change in YPR and SPR (as % of maximum obtainable) of YFT with various modifiers on the fishing mortality of the "FAD" and "other" fleets. The current level of fishing mortality is indicated by the point at the multipliers 1.0 and 1.0.

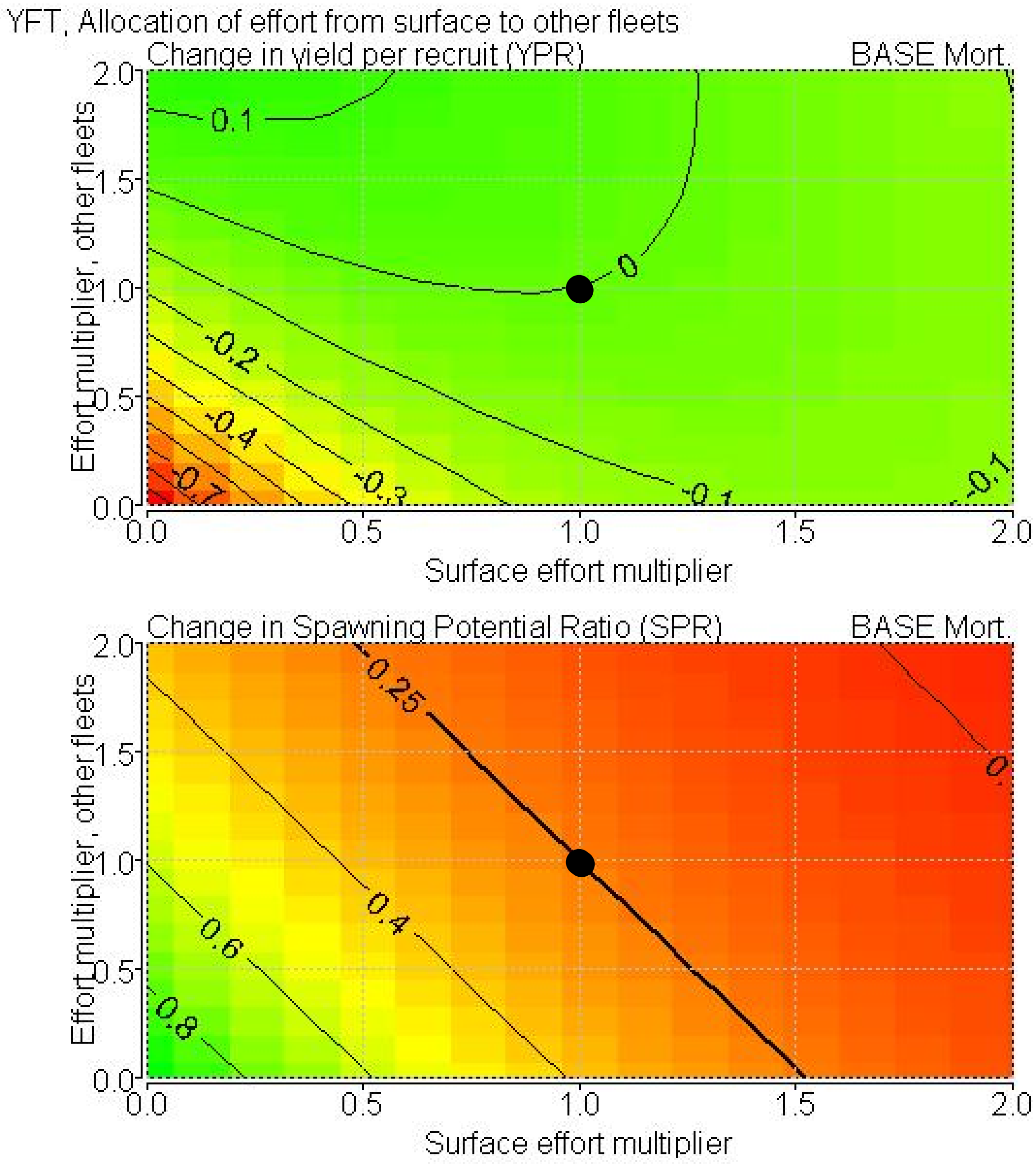


Figure 21. Percent change in YPR and SPR (as % of maximum obtainable) of YFT with various modifiers on the fishing mortality of the "surface" and "other" fleets. The current level of fishing mortality is indicated by the point at the multipliers 1.0 and 1.0.

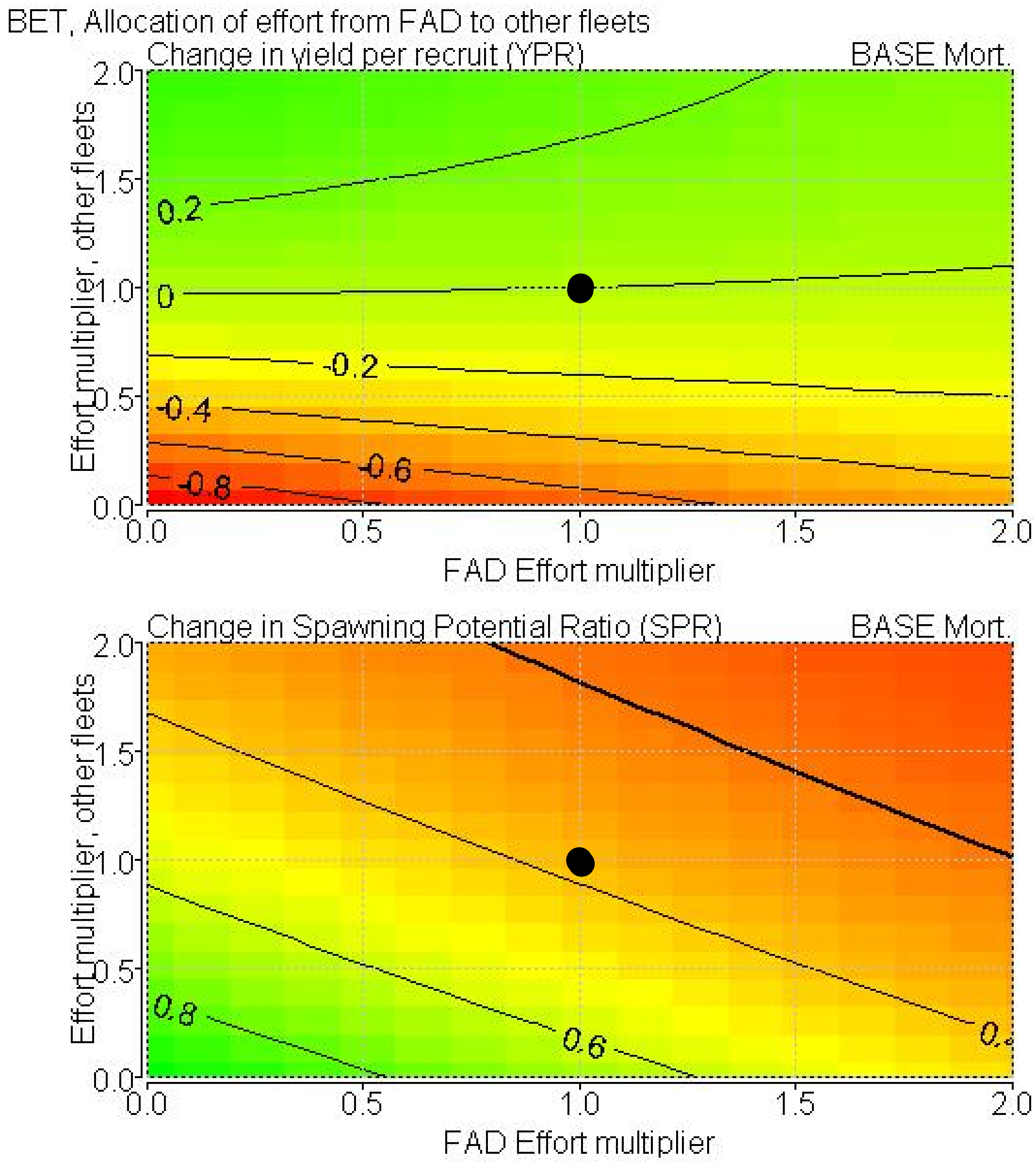


Figure 22. Percent change in YPR and SPR (as % of maximum obtainable) of BET with various modifiers on the fishing mortality of the "FAD" and "other" fleets. The current level of fishing mortality is indicated by the point at the multipliers 1.0 and 1.0.

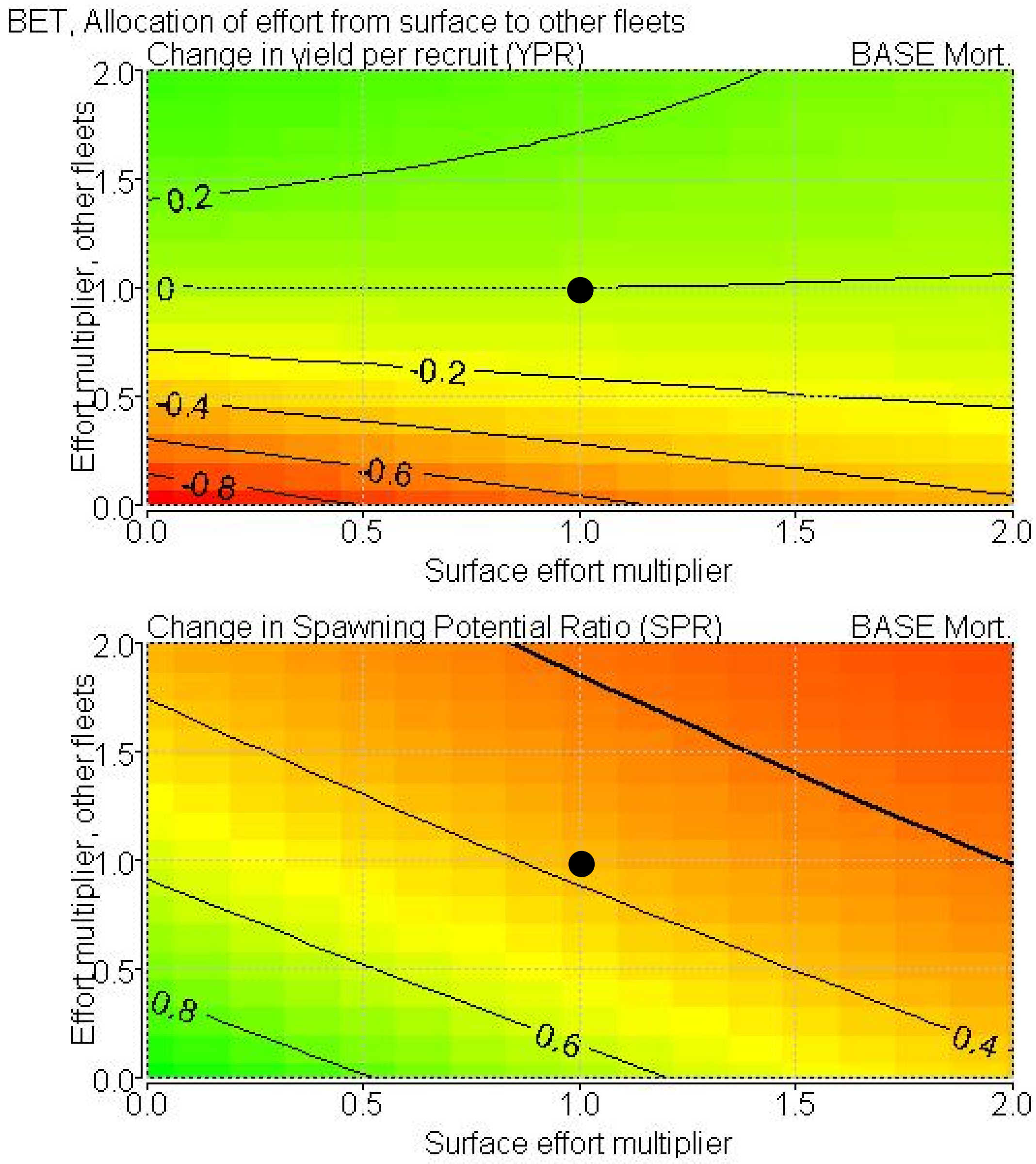
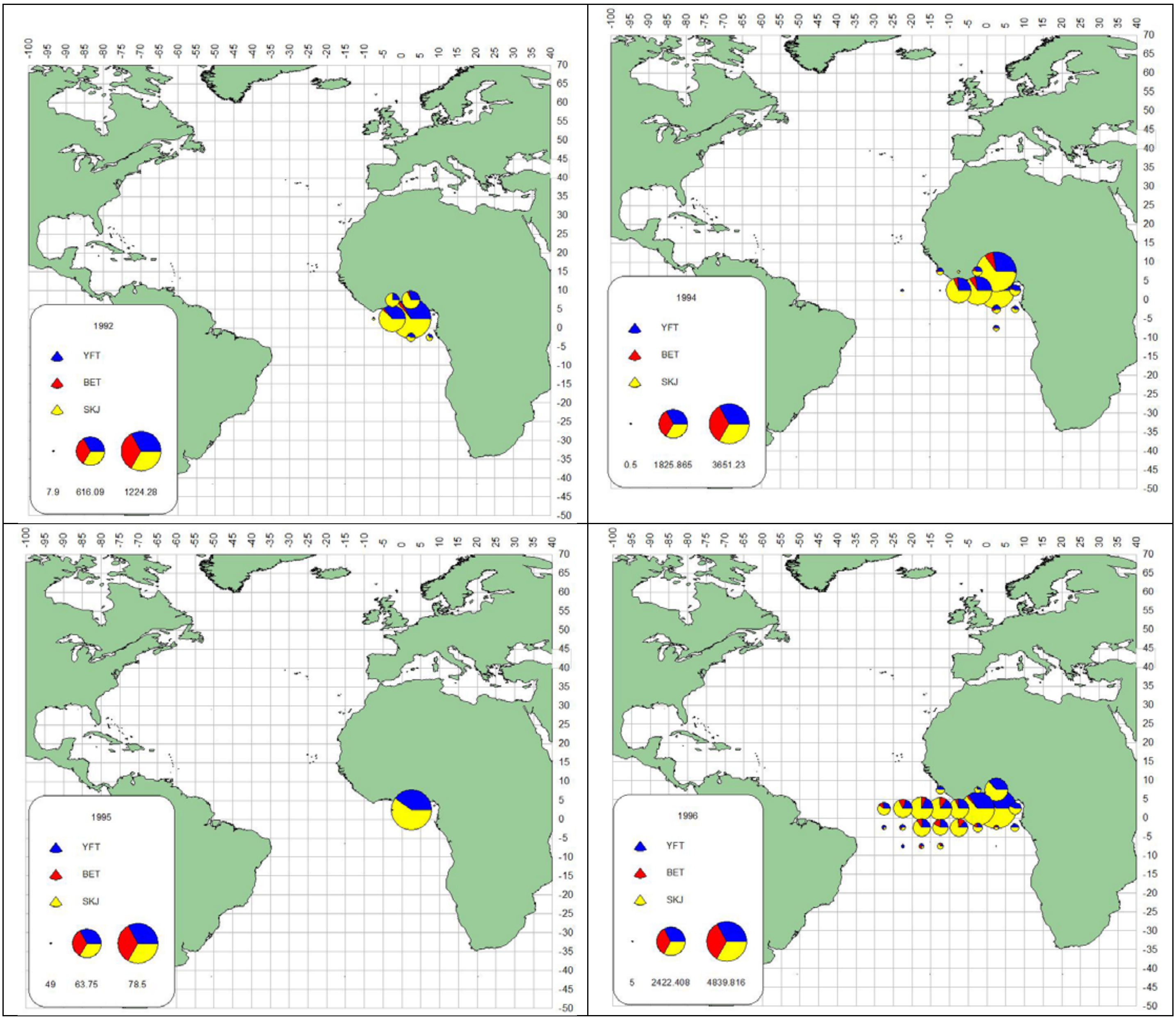
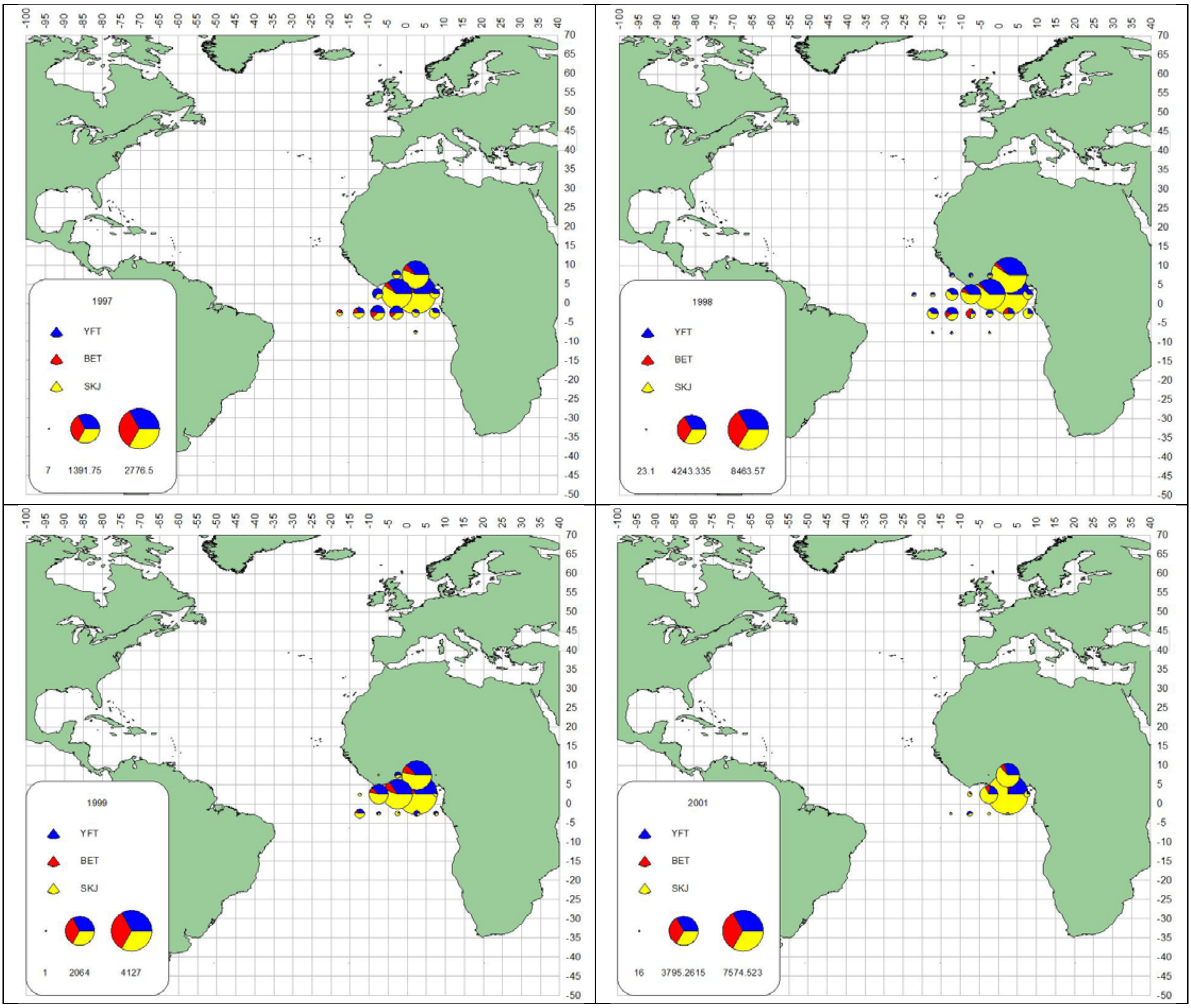


Figure 23. Percent change in YPR and SPR (as % of maximum obtainable) of BET with various modifiers on the fishing mortality of the "surface" and "other" fleets. The current level of fishing mortality is indicated by the point at the multipliers 1.0 and 1.0.


1992
YFT
BET
SKJ
7.9
616.09
1224.28
1994
YFT
BET
SKJ
0.5
1825.865
3651.23
1995
YFT
BET
SKJ
49
63.75
78.5
1996
YFT
BET
SKJ
5
2422.408
4839.816


1997
YFT
BET
SKJ
7
1391.75
2776.5
1998
YFT
BET
SKJ
23.1
4243.335
8463.57
1999
YFT
BET
SKJ
1
2064
4127
2001
YFT
BET
SKJ
16
3795.2615
7574.523

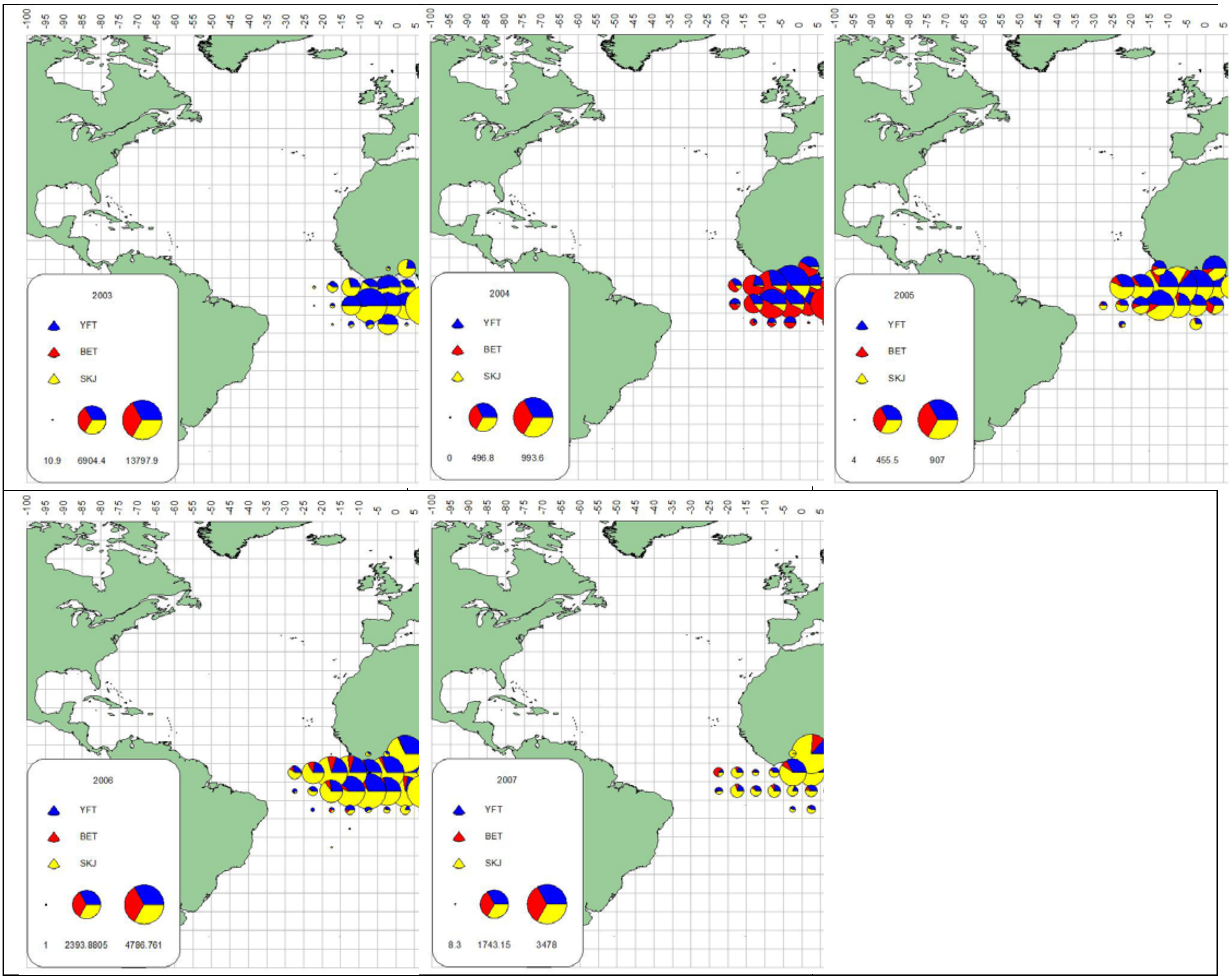


Figure 24. Catch distribution by species and year from Ghanaian logbook.

Appendix 1

Agenda

1. Opening, adoption of the Agenda and meeting arrangements.
2. Review of historical and new information on biology and fisheries
3. Review of progress on data-mining efforts to recover historical tagging data and other information
4. Analyses of tagging data
    - 4.1. Stock Structure
    - 4.2. Growth
    - 4.3. Natural mortality
5. Evaluation of alternative time/area closures for reducing juvenile catches
    - 5.1 Past closure [Rec. 99-01]
    - 5.2 Current closure [Rec. 04-01]
    - 5.3 Closure proposed in Annex 1 of [Rec. 08-01]
    - 5.4 Other alternatives
6. Evaluation of port sampling programs
    - 6.1 Description of current programs, by fleet
        - Species composition
        - Magnitude of catches
        - Estimates of "faux poisson" catches
    - 6.2 Strengths and weaknesses of current programs
    - 6.3 Potential improvements
7. Other matters
8. Recommendations
9. Adoption of the report and closure

Appendix 2

List of Participants

CONTRACTING PARTIES

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Appendix 3

List of Documents

SCRS/2009/034	Preliminary review of tropical species information held in ICCAT tagging data base. Kebe, P.
SCRS/2009/035	Preliminary analysis of the bigeye tuna (*Thunnus obesus)* caught incidentaly by the Moroccan longline fleet targeting swordfish in the Atlantic during the period 2003-2007. Abid, N., Idrissi, M. and El Omrani, F.
SCRS/2009/036	Review of sampling methodology for tunas in Ghana. Bannerman, P.
SCRS/2009/037	A proposal for examination of yellowfin tuna growth using statistical catch-at-age model diagnostics. Schirripa, M.
SCRS/2009/038	Evaluating the impact of time-area closures on the YPR and SPR of Atlantic tropical tunas under various assumptions regarding natural mortality. Cass-Calay, S.L.
SCRS/2009/039	Simulating movement to evaluate the abundance indices of Atlantic bigeye and yellowfin tuna. Carruthers, T. and McAllister, M.

SCRS/2009/040 On the sensitivity of virtual population analysis results for Atlantic yellowfin tuna (*Thunnus albacares*) to an alternative growth model assumption. Brown, C.A. and Cass-Calay, S.L.

SCRS/2009/041 An overview of fishery data in relation with the implementation of the seasonal moratorium on FAD fisheries in the Atlantic. Fonteneau, A.

SCRS/2009/042 Estimate of the non-linear growth rate of yellowfin tuna (/Thunnus albacares/) in the Atlantic and in the Indian Ocean from tagging data. Gaertner, D.

SCRS/2009/043 Manual de muestreo en puerto de túnidos tropicales en los océanos Atlántico e Indico. Sarralde, R., Pianet, R., Delgado de Molina, A., Dewals, P., Ariz, J., Herve, A., Santana, J.C., Pallarés, P., Dedo, R. and Areso J.J.

SCRS/2009/044 A potential framework for investigating the effects of moratoriums in the ICCAT region using standardised EU Purse Seine CPUE. De Bruyn, P.